Investigating quality issues after the introduction of humidifiers into table grape pack houses: A Northern Cape case

by

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Abstract

Introduction & Background to study: South Africa is the third largest producer of table grapes in the southern hemisphere following Chile and Peru respectively. Deciduous fruits and vegetables are South Africa's second most exported horticultural products. Table grapes form part of this export category. Post-harvest physiological disorders such as brown stems, decay and other quality defects have a negative impact on the quality of table grapes exported from South Africa. Within the agricultural sector of South Africa, the table grape industry has drawn major attention over the past few years as the demand for table grapes has increased considerably. However, Company Y has identified many quality issues as a cause for concern.

Purpose & problem definition / main research question Objectives: While conducting investigations along the supply chain, other industry market players have found that the implementation of a certain type of humidifier into pack houses decreases the number of quality issues faced by table grapes. Company Y implemented this humidifier system into one of their pack houses and did not install this system in the other six pack houses that data was collected from. The purpose of this study was to determine whether an investment in this humidifier system is justified, if proven to decrease quality problems for the table grapes distributed.

Methodology (scope declared): Relative humidity, ambient temperature and quality control data was collected over a period of three table grape seasons, namely November 2015 to February 2018. The data collected from Farm 1's pack house, which had the humidifier system installed, was compared to six other pack houses and against the data from Farm 1's pack house prior to the system being installed. Quality control messages were collected at the port of destination, which were linked back to the pack location (farms) where the grapes were harvested.

Main findings: The results from the statistical data analysis revealed that there is a significant relationship between the pack house with the humidifier system installed and the ambient temperature, causing fewer quality control messages to be detected. Other analysis and results supported the fact that fewer quality control messages were identified at Farm 1's pack house after the installation of the humidifier than any of the other pack houses. The results show that Farm 1 experienced the least number of quality problems. Results also revealed that higher levels of humidity and lower temperatures were maintained at Farm 1's pack house after the installation of the humidifier than any of the other six pack houses.

Main Conclusions: This research finds that the installation of the humidifier system provides positive results whereby fewer quality issues are experienced and recommends investing in the system across multiple table grape pack houses. The installation of the humidification system can be implemented as a standalone source of improvement for the quality of table grapes harvested. Furthermore, this study recommends tighter control of the cold chain within the pack house, which could reveal stronger results in future studies.

Keywords: Ambient temperature; Cold chain; Quality; Relative humidity; South Africa; Supply chain; Table grapes.

Opsomming

Inleiding & Agtergrond tot studie: Suid Afrika is die derde grootste tafeldruif-produsent in die suidelike halfrond naas Chili en Peru onderskeidelik. Sagtevrugte en groente is Suid Afrika se tweede mees tuinbouprodukuitvoerder. Tafeldruiwe vorm deel van hierdie uitvoerkategorie. Na-oes fisiologiese afwykings soos stamroes, verotting en ander defekte het 'n negatiewe impak op die kwalitieit van die druiwe wat van Suid Afrika uitgevoer word. Met die beduidende toename in die aanbod vir tafeldruiwe het die bedryf baie aandag daarop gevestig in Suid Afrika se landbousektor. Maatskappy Y het eger verskeie kwaliteitsprobleme geidentifiseer wat rede is tot kommer.

Doel van studie en definisie van die probleem / Belangrikste navorsingsdoelwitte: Gedurende die ondersoek van die voorsieningsketting deur ander rolspelers in die bedryf, het hulle bevind dat die implementering van 'n sekere tipe bevogtiger in die opbergingstore, die aantal kwaliteitsprobleme wat by tafeldruiwe voorkom, verminder het. Maatskappy Y het hierdie bevogtigerstelsel segs in een van hulle opbergingstore geimplimenteer, en nie in die ander ses opbergingstore waar data ingesamel is nie. Die doel van die studie was om vas te stel of 'n belegging in die bevogtigerstelsel geregverdig kan word indien kwaliteitsprobleme van die tafeldruiwe wat versprei word, sou verminder.

Metodologie (omvang verklaar): Data met betrekking tot relatiewe humiditeit, aanvoelbare temperatuur en kwaliteitskontrole, is oor 'n tydperk van drie tafeldruif-seisoene, van November 2015 tot Februarie 2018, ingesamel. `Die data wat ingesamel is by die opbergingstoor op Plaas 1 waar die lugbevogtigersisteem geinstalleer is, is vergelyk met die data van die opbergingstoor voor die lugbevogtigersisteem geinstalleer is. Kwaliteitskontrole-boodskappe is by die plek van bestemming versamel, en is dan weer terug herlei na die opbergingstoor (plase) waar die druiwe ge-oes is.

Hoofbevindinge: Die bevindings van die statistiese data-analise het 'n beduidende verhouding tussen die lugbevogtiger en die aanvoelbare temperatuur in die opbergingstoor waar die bevogtiger geinstalleer is, getoon. Gevolglik is daar ook minder kwaliteitskontrole-boodskappe waargeneem. Ander analises en verslae het bevindinge van minder kontroleboodskappe bevestig by die opbergingstoorvan Plaas 1, na die installasie van die bevogtiger teenoor die ander pakhuise. Die bevindinge het getoon dat Plaas 1 die minste aantal kwaliteitsprobleme ondervind het. Die uitslae het ook getoon dat hoër vlakke humiditeit en laer temperature onderhou is by Plaas 1 se opbergingstoor, na die installering van die bevogtiger as by enige van die ander ses store.

Hierdie navorsing het bevind dat die installasie van die bevogtigersisteem positiewe resultate toon en daar minder kwaliteitsprobleme ondervind is. Die aanbeveling is dat daar in die sisteem belê word in ander tafeldruif-opbergingstore. Die installasie van die bevogtigersisteem kan as 'n alleenstaande bron van kwaliteitsverbetering van die kwaliteit van tafeldruiwe geimplementeer word. Verdermeer is die aanbeveling van hierdie studie dat die koueketting in die opbergingstoor strenger gekontroleer wat gevolglik beter resultate in toekomstige studies kan toon.

Sleutelwoorde: *Aanvoelbare temperatuur; Koue ketting; Relatiewe humiditeit; Suid Afrika; Voorsieningsketting; Tafeldruiwe.*

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CHAPTER 1: INTRODUCTION

1.1 Introduction

The fruit industry in South Africa (SA) has grown steadily after the deregulation of agriculture in 1997. Prior to SA's trade reforms, trade bans restricted growth for the various industrial and agricultural sectors. These trade bans controlled exports, imports and trade relationships between SA and the rest of the world. Today, after deregulation, SA producers are free to trade across the globe. Since this deregulation, local farmers can produce more and participate in trade freely. A sector of the agricultural market that benefitted from this deregulation is the table grape industry.

According to Sandrey & Vink (2007: 325), SA's main exports, at the end of the 19th century were wool, fruit and wine. These contributed 58% of the total agricultural exports in 2004. Although the percentage is still similar today, this aggregation hides several underlying trends that shows the sector has been relatively dynamic. As stated by Sandrey & Vink (2007: 325), within the fruit industry, both avocados and table grapes have shown considerable growth in their market share of the total sector. Wool, which was once the dominating commodity of the sector's total exports, has become somewhat insignificant. The shift in demand for table grapes, which dominates South Africa's agricultural exports currently, supports the need for this study.

Another underlying concern in the industry is post-harvest cold chain maintenance. In a cold chain study conducted by Freiboth, Goedhals-Gerber, Van Dyk & Dodd (2013) on postharvest management, temperature management was identified as one of the most vital elements. Freiboth, *et al* (2013) continue further to say that even slight variations in temperature can cause a significant impact on the shelf life and value of fresh produce. The importance of temperature management is amplified, as any break in the cold chain at any point along the supply chain will reduce the shelf life of the fresh produce.

Table grapes differ from other varieties of grapes, as the table grape is not used to produce wine, dried for raisins or squeezed for juice, but are harvested to be consumed fresh. Compared to wine grapes, table varieties usually have a lower sugar content and are more flavourful when eaten (SATI, 2017). They are cultivated, harvested, packaged and transported to reach the final consumer. Their quality deliverables such as look, taste and shelf life are thus vital to the end consumer, producers and distributors. Although, the supply chain may seem simple, there are many variables that affect the quality and shelf life of the table grape. Some of the major influences on the quality and shelf life of this grape type are temperature control, relative humidity, packaging and handling. Poor quality grapes that are being distributed both locally and internationally has been a problem within the industry, as more produce is thrown away as waste than is consumed by the customer. This also causes high financial losses to third party distributors who take ownership of the product, but are not guaranteed the quality of grapes that reach its customers.

Like many other fruits in the South African fresh fruit industry, table grapes have experienced substantial growth in value over the last few years. Consumers both locally and internationally want to enjoy fresh fruit all year round. As the value in this industry is increasing, SA farmers are becoming more aware of the impact and want to produce larger volumes to achieve more sales, both domestically and internationally. As sales, both internationally and locally, are dependent on the quality and shelf life of table grapes, the table grape industry is constantly looking for ways to improve these aspects. The way in which table grapes are harvested, packed and transferred can define role players in this competitive market and, therefore, supply chain management in the table grape industry is one of the aspects that can be improved and could add great value to the industry. This research may add vital knowledge of post-harvest management to various players in the industry where higher quality table grapes can be distributed from local farms.

One of the latest discoveries and "improvements" in the industry is the implementation of humidifiers. It is believed that by installing humidifiers into various process stages, post-harvest, this could improve the quality of grapes sold. Humidifiers add moisture to the air by releasing water vapour, increasing relative humidity. Relative humidity is important for table grapes as sufficient moisture enables the fruit and other structures i.e. stems to not respire and dry out. The ideal relative humidity should be maintained at 95% and should not increase higher, as this could lead to berry cracking and various other quality issues (Pinto, Schorr, Thewes, Ceconi, Brackmann & Fronza , 2015).

This study addresses the quality issues that the industry faces by identifying the relative humidity and ambient temperature of table grapes at post-harvest pack houses to the point of sale. The researcher found interest in this topic of study, because if the results reveal positive results for the implementation of a humidification system at post-harvest pack houses, this could change the way all table grape farmers manage temperature and humidity within their pack houses. This study could benefit logistics and supply chain participants by enabling them to supply better quality products and reduce quality claims and, therefore, reduce cost to company.

1.2 Background

In 2015, one of the largest table grape producers and exporters in the Western Cape (WC) province of SA, decided to introduce humidifiers into their pack houses, to reduce quality claims. In this study, this company is referred to as Company X.

The background behind the decision to introduce humidifiers into Company X's pack houses was linked to the fact that the farm wanted to give their grapes the best possible post-harvest treatment, as the grapes already received the best possible treatment in their vineyard (Jansen, 2017). The idea behind installing humidifiers into this farm's pack houses was to increase relative humidity within the pack houses. Increasing the relative humidity counterbalances the deprivation of moisture between the table grapes and its surrounding atmosphere. If the surrounding atmosphere is drier than the grapes, moisture is drawn out of the grape into the surrounding atmosphere and that is when post-harvest decay occurs (Jansen, 2017). A representative from the business, who supplied and installed the humidifiers, stresses the importance of post-harvest treatment to the table grapes. In 2017, it had been Company X's second year of using humidifiers. Both the CEO of Company X and the supplier of the humidifiers, who are strong supporters of this "new" treatment, vouch that they had experienced substantial improvement in quality, significantly fewer quality claims and the table grapes looked much better, with greener stems (Jansen, 2017). The use of dry humidity (i.e. moisture cannot be seen or felt) had proved to be a success for Company X, however, for this to be an industry wide application more farms need to test this treatment.

Company Y, a table grape exporter that has had considerable interest in what Company X is claiming, proposed this study to investigate the effects on the quality of table grapes they deliver, after implementing humidifiers into one of their pack houses.

Company Y distributes table grapes of various farms that harvest in the Northern Cape of South Africa. Farms follow a similar process of harvesting, cleaning and packing the table grapes in the Northern Cape. The grapes are cooled for fourteen to eighteen hours and then transported by reefer trucks to one of two storage warehouses in Cape Town. Thereafter, according to the shipping schedule, the grapes are packed into reefer containers and transported to the Port of Cape Town. From there, containers are loaded onto vessels to ship them to their port of destination across the world. At the receiving port, grapes are checked. Any quality, logistical or financial claims are identified at this point. This study investigates claims identified at the port of destination. Once the grapes are quality checked, they are transported directly to retailers to store or to sell immediately. To identify whether humidifiers have an effect on the quality claims Company Y receives, one of the farms had a humidifier system installed at the precool stage on the farm, whereas the other six farms continued without any changes implemented.

This study attempted to determine the relationship between the quality claims identified and the installation of the humidifier system, by measuring the ambient temperatures and relative humidity percentages of the pack houses. This was done by using data that was supplied by Company Y. In addition, the study examined the influence of temperature and humidity on table grapes by executing a literature review.

1.3 Motivation

The loss of table grapes due to quality concerns becomes a highlighted problem when it contributes to global food waste. According to the Food and Agriculture Organization of the United Nations (FAO, 2016), it is estimated that of the food produced globally, for human consumption, one-third of it is wasted or lost along the supply chain. That equates to almost 1.3 billion metric tons of food that does not reach the final consumer (FAO, 2016). The FAO goes further to say that most of the food loss takes place during transit “from farm to fork”. Food loss does not only represent the food product being lost but represents wasted resources such as land, energy, water, financial, mechanical inputs and agrichemical. In a world of declining resources and increasing costs, focus is placed on saving resources. Food loss does not only impact producers, farmers and distributors with reduced income and increasing consumer costs, but it also challenges overall food security (FAO, 2016). The FAO estimates that saving a quarter of food products lost or wasted globally could possibly be enough to feed 870 million hungry people in the world (FAO, 2016). Numerous studies have been conducted whereby it was observed that an underlying cause of post-harvest food loss transpires at early stages of the food value chain (FAO, 2016). This was associated with one of the reasons being the lack of intermediate processing in the production catchments (FAO, 2016).

In South Africa, in terms of value, the fruit industry is the largest contributor to the country’s agricultural exports (DAFF, 2018). It is approximated that ninety percent of SA’s fruit is exported to international markets whereby the remaining portion is processed and consumed locally. SA’s fresh fruit industry attains more than fifty percent of its income from exports and provides permanent employment to an estimated 460 000 people (DAFF, 2018). The fresh fruit industry is considered a vital employer in the South African economy and is therefore important that the industry remains to be sustainable, profitable and internationally competitive. One of the ways in which the industry can develop and maintain its global competitiveness is to develop technological advancements in the post-harvest leg of the value chain of fresh fruit.

1.4 Problem Statement

Company Y is currently experiencing defects in the quality of table grapes that they distribute. Defects include berry cracking, dry stems and water loss amongst others. Such defects may be due to problems caused by temperature control, relative humidity, post-harvest handling and/or packaging. These quality issues have negative effects on the shelf life of the fruit, thereby decreasing Company Y's competitiveness locally and internationally. Company Y, is interested to know whether the introduction of humidifiers may inhibit some of these defects. Therefore, this research investigates whether the use of humidifiers affects the quality of table grapes that the farmers intend to sell. Although there may be many variables that could affect the quality and shelf life of table grapes, this research investigates the impact that relative humidity and storage temperature have on the quality and shelf life of the table grapes, post-harvest. The investigation is limited to precool and pack house storage, before distribution while several grape cultivars are investigated. This is done to eliminate the risk of missing valuable insight into the quality problems.

1.5 Aim and Purpose of the Study

In section 1.2, Company X claimed that the installation of humidifiers into their table grape pack houses had significantly increased their quality, reduced their quality claims and their grapes were looking much better. As this is currently, only a claim made by Company X, and no other evidence was found that shows this is accepted practice, this leaves a gap in knowledge. This research aimed to prove whether these claims by Company X are valid and if they are significant enough to make large capital investments into this "new" treatment. The purpose of this study is to improve the quality of table grapes distributed in and from South Africa. Furthermore, extending the shelf life of grapes could add significant value to Company Y and the South African table grape industry in its entirety.

This research intends to add value to the logistics field and table grape industry in South Africa. South Africa is not a first world country, but it competes with international giants without having the same technological advancements and other capabilities of these countries. This study aims to prove that simple changes that do not necessarily involve great capabilities or exorbitant capital, could improve South Africa's share and value in the market. In addition, this study aims to reduce the levels of table grapes that are disposed of as waste by supplying better quality products.

1.6 Research Objectives

The main objective of this study is to provide meaningful results that add value to the South African table grape industry. This research investigates whether the implementation of humidifiers in precool storage and pack houses would help to limit the Quality Control (QC) problems within the table grape industry.

Below is a list of the objectives of this study:

- Identify quality issues faced by the table grape industry in the Northern Cape.
- Identify the source of quality problems faced by the table grape industry in the Northern Cape.
- Provide results and recommendations to improve temperature and humidity management within the table grape industry in the Northern Cape.

1.7 Research Questions

The problem statement is solved with the help of the following research questions:

1. Does the implementation of humidifiers increase relative humidity at table grape pack houses in the Northern Cape?
2. Does the implementation of humidifiers decrease ambient temperature at table grape pack houses in the Northern Cape?
3. Does the implementation of humidifiers show a relationship between implementing the humidifiers and the quality of table grapes harvested in the Northern Cape?
4. Can humidifiers be implemented as a standalone source of improvement for the quality of table grapes harvested in the Northern Cape?

1.8 Research Chapter Outline

The foundation of this thesis is built on this first chapter that highlights the problem statement, research questions, objectives and aim that this research intends to solve. This chapter provides a background and motivation for this research. Ultimately, the goal of this research is to provide enough evidence to answer the research questions stated in this first chapter.

In the second chapter, various sources of literature are reviewed to provide credible sources of information that underpins the research. It provides an overview of the current practices in the table grape industry in South Africa and some of the best practices that other major table grape producing countries in the world follow.

The third chapter provides a step-by-step method of how this study was conducted. It outlines the design and data collection process that was followed to achieve the stated objectives of this study.

Chapter 4 provides the data analysis. This chapter reveals statistical information in the form of graphs and tables and forms the basis on which chapter five is built upon.

Chapter 5 includes the interpretation of the results revealed in Chapter 4. Furthermore, this chapter provides possible reasons for the results disclosed in the previous chapter. This chapter is vital and assists stakeholders in the decision making process. It provides the stakeholders involved, with sufficient evidence to make certain changes or the need to investigate further.

Chapter 6 of the research is the conclusions chapter. It answers the aim, objectives and research questions within this study. It highlights the main findings of the research. In addition, it provides recommendations to the table grape industry of areas that need improvements.

This research concludes with the final chapter providing possible areas for future research.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

There are various factors that influence the growth of the table grape industry in South Africa. Factors include the exchange rate, the climate and global warming (which has led to major drought concerns), harvest methods, packaging and the supply chain. Although this study focuses on humidification and its impact on quality, the literature review provides an evaluation of the previous and current works that have been conducted relating to this research area and any influences that can be ruled out that have possible effects on the results of this research. In this study, all subject matter is interrelated and it is therefore important for readers to understand the underlying theory that underpins this research.

The literature review is broken up into different sections to provide insight on various themes for both the researcher and the reader. The literature review begins with the first section, the introduction, which provides context to this study of table grapes and its relevance in the field of Supply Chain Management (SCM). It then investigates themes such as the table grape industry in South Africa, temperature, humidity, previous studies and global warming. The penultimate section looks into current international best practices and finally, the chapter concludes by highlighting important takeaways from the literature reviewed.

2.2 Table Grapes

Fruits, vegetables and leaves are living parts of a plant and are comprised of approximately 5% to 95% by water. These living parts decay and die. This is due to the food and water reserves being exhausted (Kasmire & Cantwell, 2011). There are certain elements such as high temperature, humidity and physical bruising that increases the rate at which the fresh produce loses food and water. This, therefore, leads to an increased likelihood of losses (Kasmire & Cantwell, 2011).

Table grapes are widely known for their high nutritional therapeutic value. However, they tend to deteriorate easily, because of pathogen infection, due to their features of being soft and having a high moisture content (Xiao, Wang, Zhang, Chen & Li, 2015). These characteristics often make table grapes susceptible to quality and safety issues. One of the main ways in which to diminish these issues is the use of a controlled cold chain to ensure that the grapes are always stored in a low temperature environment by using artificial refrigeration technology throughout the supply chain. The ideal storage temperature of table grapes is -0.5°C to +2°C, which can extend the shelf life of the grape for 45 to 50 days (Xiao, *et al*, 2015). Temperature control is used to reduce the quality losses of the grapes (Xiao, *et al*, 2015).

Table grapes have various cultivars (varieties), which are grown from *Vitis Vinifera L* (Common Standards of Quality for Table Grapes, 2013). They are supplied fresh to the end consumer, unlike other grape varieties that are used for other industrial purposes such as wine, dried fruit or juice making. Table grapes are non-climacteric fruit; they do not continue to ripen after harvest. In this study, several varieties are investigated, including the two most commonly exported varieties, prime seedless and flame seedless.

The prime seedless grape was South Africa's earliest seedless variety. It has a green / yellow colour with a light "Muscat" flavour. It is often termed the "white" grape. It has a fresh, crispy taste and ripens later in the year, during the month of November (DAFF, 2012). The flame seedless grape was South Africa's first red seedless grape variety. Its colour is bright red, with a sweet taste and is ready for harvest in December (DAFF, 2012).

As the world gets more advanced and more rights are given to the consumer, producers and manufacturers want to do whatever it takes to please the end consumer. One of the requirements that consumers are expecting, is to have fresh produce available all year round. However, each fresh product has a season in which it can be produced and has a certain timeframe in which it remains fresh. Today, through many technological advancements and controls, the shelf life of fresh produce can be prolonged. Therefore, the supply chain and its controls play such a vital role in fresh produce.

2.3 Definition of a Supply Chain

A generic supply chain incorporates all supply chain processes along the flow of products and services, from raw state to finished state. A Supply Chain (SC) is the network of vehicles, facilities and Logistics Information Systems (LIS) connected by an organisation's supplier's suppliers and its customer's customers (Frazelle, 2002). A supply chain encompasses the interaction between various role-players who influence the product as it moves along the supply chain (du Toit, Deidre & Vlok, 2014). In layman's terms, it is a chain connecting harvested/produced products all the way to the end consumer.

SC operations necessitate managerial processes that stretch beyond functional areas within individual firms. These SC operations link trade partners and customers beyond the boundaries of the organisation. The SC is driven by the forward and reverse flow of three key inputs, namely, *information, materials* and *finances* (Frazelle, 2002).

2.3.1 Types of Supply Chains

There are various types of supply chains. Five main types are explained further in this study.

1. **Make to Order (MTO)**. This is a SC where manufacturing only begins once an order is confirmed. It is also known as "pull type" SC operations, because manufacturing is driven

by real time demand and inventory required to manufacture the finished product is acquired only once it is needed. Thus, being "pulled" by demand. If an organisation used a MTO supply chain, there is no need to store finished goods, but there will be a need to store raw materials and componentry (Types of supply chains, 2017).

2. **Make to Stock (MTS)**. This is a SC where manufacturing is driven by demand forecasts. Demand forecasts, if estimated correctly, can prevent excess inventory and opportunity cost due to stock outs. Often an Enterprise Resource Planning system is used to provide visibility of inventory and probe stock replenishment efficiently (Types of supply chains, 2017).
3. **Build to Order (BTO)**. In this model, the assembly of the customers' order starts almost immediately from time of receipt. The management of the SC requires careful planning and control of needed inventory and supplies. This type of SC model supports the concept of "mass customization" (Types of supply chains, 2017).
4. **Channel Assembly Model (CAM)**. This type of SC is a slight modification to the BTO model. The inventory required for the finished product is gathered and assembled at different points along the distribution chain. This is achieved through strategic partnerships with third part logistics (3PLs) operators. The third party service providers either assembles products at their facility or provides collection and delivery of finished product/s to customers (Types of supply chains, 2017).
5. **Continuous Replenishment Model (CRM)**. This model is most applied to supply chains that have fairly stable demand patterns. The idea of this model is that inventory will be constantly restocked by working closely with suppliers and intermediaries. However, if this process requires many shipments, the costs may be too high, which could cause the SC to collapse (Types of supply chains, 2017).

The type of SC model used in various organisations and environments depends on what the customer seeks, what companies have identified works well for them and more intrinsically, depends on the type of inventory moved throughout the SC. There are numerous types of inventories such as raw materials, work in progress and packaging, to a name a few. In this research, the type of inventory that is being studied falls under raw materials and is further segmented into fresh agricultural produce. The produce being distributed is fresh and has a short shelf life and therefore a **Make to Stock (MTS)** model is used in the table grape industry. The type of SC used has further complexities added when the type of inventory moving through the distribution chain is perishable.

2.3.2 Conventional SC versus Perishable Goods SC

The fundamental difference between a conventional SC and a perishable goods SC is the sensitivity of the product or material being moved along the SC (Frazelle, 2002). The temperature within the perishable goods SC, if not controlled and monitored constantly, can cause severe product damage and therefore financial losses. A conventional supply chain is a global network used to deliver products and services from raw materials to customers, through an engineered flow of information, physical distribution and cash. The fundamental difference between a conventional SC and a cold chain is the product or material sensitivity (Khan *et al*., 2017:97).

Table 1 tabulates some of the advantages and disadvantages of the traditional SC. Highlighted under "advantages" in the table are some of the important benefits added, such as centralised control, relative certainty about prices, high productivity, etc. If products were not able to be stored in controlled temperatures, perishable products could not be made-to-stock. Products would deteriorate more rapidly once harvested.

2.3.3 The Cold Chain

The Perishable Products Export Control Board (PPECB) describes the cold chain as the "seamless movement of fresh, chilled or frozen products, from the production area to the market, through various storage and transport mediums, without any change in the optimum storage temperature and relative humidity" (Cold Chain management, 2019). An unbroken cold chain is an uninterrupted series of storage and distribution activities that are maintained at a given temperature range. The cold chain is used to help extend and ensure the shelf life of products such as fresh agricultural produce.

There are many key role players in the SC, which leaves room for error and requires close control and management. This results in the need for Supply Chain Management (SCM).

Table 1: Advantages and Disadvantages of traditional SC concepts

Element	Disintegration		Vertical Integration	
	Advantages	Disadvantages	Advantages	Disadvantages
Controllability	Small span of control	Decentralised control; Bad controllability; non-transparency	Centralised Control; Good controllability; transparency	Large span of control
Compatibility	Remaining flexible and creative	incompatibility; incoherence	Compatibility of products; synchronised systems	Getting stuck in fixed procedures and mind-set; non-creativeness
Standardization	High customization and exclusiveness of products	No standardisation; fitting problems of components	Advanced standardisation; well-fitting components	Restricted ability to meet customer demands
Risks	Independent businesses; low fixed costs and assets	Uncertainty about prices and deliveries of supplies	Relative certainty about prices and deliveries of supplies	Ownership of business; High fixed cost and assets
Flexibility	Flexible to various changes; external attentiveness	Unpredictability of supplies	Predictability of supplies	Relative inflexibility to market changes; loss of attentiveness
Transaction costs	Variable costs	High transaction costs	Low transaction costs	Fixed costs
Efficiency		Low internal efficiency	High internal efficiency	
Productivity		Low productivity	High productivity	
Inventory	Make-to-order; small risk of piling up inventory	Uneasy inventory control along the supply chain	Easy inventory control along the supply chain	Make-to stock; many buffers to assure smooth production
Speed	Fast adjustment to external changes	Slow process; slow transmission of information through the supply chain	Fast process; Fast transmission of information through the supply chain	Unwieldiness to external changes; high "impact of collision" when some part of the process falls back
Cycle Time	Low risks of "backdoor inventory	High cycle time	Low cycle time	High risks of "backdoor inventory"
Dependency	Small damage when supply chain malfunctions	Incoherence	Coherence	Great damage when supply chain malfunctions

Source: Vrijhoef, 1998

2.4 Supply Chain Management

According to the Council of Supply Chain Management Professionals (CSCMP), "Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion and all logistics management activities. Fundamentally, it also includes the co-ordination and collaboration with channel partners, which include suppliers, third party service providers, intermediaries and customers (CSCMP, 2019). SCM, in essence, integrates supply and demand management within and across companies" (Pienaar & Vogt, 2012: 8).

SCM is defined in other sources of literature as the management of supply chain assets and product, information and fund flows to grow the supply chain surplus (Chopra & Meindl, 2016). SCM encompasses a total systems approach to manage the flow of information, resources and services from raw material to the final consumer (Jacobs & Chase, 2014).

SCM includes all logistics management activities including manufacturing operations. It navigates and coordinates all processes and activities in conjunction with product design, sales, marketing, information technology and finance (Pienaar & Vogt, 2012: 8). All "links" in the SC are vital for the efficient and effective flow of goods. One of the major focuses in this study is the logistics link in the SC.

2.4.1 Logistics Management

Logistics was first introduced in the military field by a brigadier general who described logistics as the art of combining and co-ordinating the quartering, means of transport, supply and support of troops by means of reasoning and calculation during a military campaign. Using this as a foundation, logistics was thus interpreted as applying reasoning, especially using mathematical analysis and synthesis to the complexities of co-ordinating supplies to military personal and manpower (Pienaar & Vogt, 2012: 6). Simply put, logistics is the physical movement and positioning of materials from the source of supply to the point of consumption. It creates value by ensuring the right goods are at the right place at the right time.

Logistics activities on the other hand, connect and operate the objects within the supply chain (Frazelle, 2002). For example, the supply chain includes the factories, warehouses and ports, but the logistics activities connect and include everything within the supply chain, such as inventory management, transportation and warehousing, including recalls and returns. Logistics management is the part of SCM that plans, implements and controls the efficient, effective forward and reverse flow of goods, services and associated information, in order to meet customer requirements. This planning and control is from the point of origin to the point of consumption. Logistics management includes storage of goods, services and related information (Pienaar & Vogt, 2012: 8).

Frazelle (2002) uses a sports analogy to explain the concept simply, "logistics is the game played in the supply chain arena". There are many different arenas, and there are many different games, which are played at the same time. The industry could be described as the arena. Specific to the industry, there are different logistics requirements. For example, the fresh fruit industry requires temperature control throughout its distribution, whereas in the automobile industry, there would not be any temperature control requirements.

2.4.2 SC Augmentation through Logistics

Logistics plays a value added role in the SC. According to Pienaar & Vogt (2012) consumers place a certain value on a product depending on the “level” of satisfaction the consumer derives from the product. This satisfaction is retrieved from the utility that the product will have for the demander/consumer. There are four subgroups of utility that can add value to the product, namely form, place, time and possession utility. Place and time utility are created by logistics activities. A description of these two forms follows.

2.4.2.1 Place Utility

Place utility is created when goods are moved from one place to a place where their value increases i.e. where buyers are willing to pay more for them. Logistics assists in moving these goods from this place of lower value, for example, where the product is manufactured, to where they are processed into a form more useful to the buyer. Value of goods also increases for goods where the demand is high, but supply is low and vice versa. Logistics also moves goods from the point of surplus to where there is a shortage (Pienaar & Vogt, 2012: 23).

2.4.2.2 Time Utility

Time utility is created when the value of goods or services rendered increases because of it being made available when it is needed. Logistics creates time utility by means of storage and successful delivery of goods to the right place at the right time. An example of value added through logistics is when certain fresh produce, which needs to be kept in refrigerated storage, sells at a higher value out of season, when they are in short supply, than when they are in their peak season (Pienaar & Vogt, 2012: 23).

2.5 How is Logistics applied within the SC?

Logistics is the execution of moving and positioning the required goods at the required time throughout the supply chain. If materials are available earlier than required, this could subsequently store capital in inventory, cause warehouse capacity issues, shelf life issues and various other problems. If materials are available later than required, this could cause stock out issues, potential risk of making alternative plans of purchasing to cover immediate issues and other possible risks and ripple effects in the SC. There are several possible incidents that could cause problems along the supply chain. Logistics, however, plays a vital part in ensuring product availability throughout the supply chain. As mentioned previously, logistics adds value by ensuring the right product is available at the right time. In addition, the product needs to be available in the right quality. A container holding ten pallets of table grapes that arrive on time at the right place of destination has little or no value if all the products are brown and shrivelled.

2.6 Packaging and Handling of Table Grapes

The way in which table grapes are handled and packaged plays a vital role in the life span of the fruit (Ramteke et al, 2017). It is essential to store fruit at the correct temperature to inhibit further maturing and decaying of fruit.

The most desirable temperature to store table grapes at is -0.5 °C (SA flow report, 2017). At this temperature, the table grape maturing process is slowed down long enough to reach the market and would not destroy the fruit (DAFF, 2012).

Relative humidity is important for table grapes as sufficient moisture enables the fruit and other structures, including the stems, to not respire and dry out. The relative humidity should be maintained at 95% and should not increase any higher, as this could lead to berry cracking (Pinto et al., 2015). Berry cracking would prevent the grapes from being suitable for export standards.

This study investigates the quality of grapes at several pack houses, in various locations, in the Northern Cape province of South Africa. Although the relative humidity should be maintained at 95%, there are a number of factors that may influence the relative humidity. In order to control the relative humidity, humidifiers were installed at a test pack house. The results in this study compare the pack houses at standard storage conditions, where no humidifiers were used versus the test pack house with humidifiers installed. By investigating table grape pack houses across the Northern Cape Province, insight into the benefits of implementing humidifiers in pack houses across the Northern Cape can be identified.

2.7 Perishable Products Export Control Board (PPECB)

One of the controlling bodies in South Africa, ensuring exported products meet international regulations is the PPECB. The PPECB is an independent service provider of quality certification and cold chain management services for producers and exporters of perishable food products. The PPECB is a national public entity that is recognised as an approved third party under the European Commission Regulation 543 of 2011. This agreement recognises the South African inspection systems as equivalent to that of the EU inspection bodies and, therefore, ensures less frequent checks at the port of import into the EU (Perishable Products Export Control Board, 2019). As a national public entity, the PPECB is constituted and mandated in terms of the Perishable Products Export Control Act (PPEC Act), No 9, of 1983 to perform cold chain services. The PPECB also delivers inspection and food safety services assigned by the Department of Agriculture, Forestry and Fisheries (DAFF) under the APS Act, No.119 of 1990 (Perishable Products Export Control Board, 2019). Although the International Trade Administration Commission (ITAC) sets import and export control measures in South

Africa, the PPECB are able to provide a valuable service to exporters from South Africa who require certification and cold chain management services.

Antle (1999:605) describes the cold chain as a whole network that has special logistics requirements to keep goods at a specific cold temperature to maintain quality. The cold chain usually deals with perishable food items, biological tissues and vaccines. In order to maintain their expiry date and sustain quality, these products require temperature control. According to Khan *et al*. (2017:98) cold storage temperatures specific to product requirements can add valuable extension to product shelf life and is considered a significant competitive advantage.

In today's fast growing and enormously competitive business environment, organisations must consider their global reach. It is especially important for enterprises that are involved with temperature-controlled products, because a disruption in the SC can cause major losses.

The cold chain has become increasingly important within the changing global economy. This is due to the increasing demand on the products of temperature-controlled industries and services (Khan *et al*., 2017:98). These products include, but are not limited to, manufactured foods, medical vaccines, military services and chemicals.

2.8 Company Y

Company Y, which is one of South Africa's largest producers and distributors of table grapes, has been in the table grape Industry since 1997. This means that from the genesis of the agricultural deregulation in South Africa, Company Y had its hand in the industry's transformation. Although they have been in the industry for just over two decades, the company had been experiencing problems with the quality of their grapes. One of the major concerns for the company is dry stems of the table grapes. With dry stems, the table grape is not considered to be of premium quality and would be sold in domestic markets for a much lower price.

As production and trade do not only affect the South African economy, but local producers and exporters, Company Y, which exports the majority of their grapes, have invested time and other resources to identify whether there actually is a benefit in implementing humidifiers into their storage and pack houses. Company Y works closely with local farmers, exporting grapes across the globe. A few of the international markets supplied by Company Y include the United Kingdom (UK), Europe and the United States. The UK is their biggest market.

2.8.1 SC and Logistics Processes of Company Y

In the following section, a more detailed look <u>within the pack houses</u> of Company Y is shown. It shows the product flow from the point of harvest to the dispatch of Finished Goods (FG).

Further to that, the SC processes of Company Y follow. Although there are many aspects to the SC, in the depictions to follow, the complexities are excluded.

2.8.2 Harvest to Dispatch processes at Pack House of Company Y

1. The table grapes are harvested in the vineyard when the ambient temperature is less than 30°C. This process takes between 2-3 hours. Best practice would be to harvest before sunrise so temperatures are low and relative humidity is high. However, this does not always happen. Harvest times vary. The later in the day that produce is harvested, the higher the temperatures recorded and humidity levels drop.
2. The harvested grapes are then transported as quickly as possible, via tractors in plastic lugs, to the pre-cooling chamber where the field heat is removed using either one of three systems.
    a. Wet wall
    b. Air conditioner
    c. Air conditioner with humidifier

   At this stage, the ambient temperatures of the grapes are brought down to 17°C-19°C, through conductive cooling, and relative humidity (RH) is maintained at 75%-85%. The wet wall and the air conditioner with humidifier is said to maintain RH better, as these two systems add moisture to the air, whereas the air conditioner on its own, removes moisture from the air and, therefore, RH may be lower. The lugs filled with table grapes are held at this stage for up to six hours.

3. The produce is then sent into the packing line via the feeding line. The grapes are moved from the feeding line to the packing station where they are cleaned, weighed, quality controlled checked and packed into its various primary packaging (plastic punnets, plastic bags or left lose). The packaged grapes are then packed into secondary, corrugated cartons (Figure 1) and moved onto the finished product output line. This could take between 1-2 hours. The packed cartons are then moved to the palletising area where cartons are packed, stacked and strapped onto plastic pallets.

Figure 1: Secondary Corrugated Carton (Ventilated)

Source: Corrugated packaging, 2019

There are plastic tubes called “socks” that run from the pre-cooling chamber through the packing line. The cool air from the pre-cooling chamber is passed through the system to the packing line in order to maintain the temperature at 17°C-19°C. However, the back end of the pack line does not have these “socks”. Temperatures are thus higher ranging from 18°C-23°C, and RH can be found from 65%-80%.

4. The palletized produce is then sent to the holding chamber where it is stored for a short period of time (up to 6 hours) in order to build enough quantity of pallets to be sent to the forced cooling chamber. At this point, cold air is circulated into the holding chamber. The temperature is said to be controlled at 10°C and a RH of 70%.
5. It is preferred that the forced cooling chamber is packed to capacity (dependent on how big the chamber is, it can fit an average of 40 pallets in each chamber) and to not open and close the entrance doors and break the cooling process. The palletized produce goes through the forced cooling process for an average of 16 hours. As the pack houses in this study have their own forced cooling chamber, this process time is known to be shorter at an average of 16 hours, but when the table grapes are sent to the larger commercial storage facilities, at this point, the forced cooling process is known to be longer than this average time. Pack houses that are outside of the Western Cape (WC) usually have their own cooling chambers, as it is a long distance away from the commercial cooling facilities located in the WC. Pack houses within the WC can choose to not have their own cooling facilities and therefore store at the commercial facilities that are larger and therefore a longer time is needed for the forced cooling process.

   The cold air forced into the chamber is at a temperature of -1°C. However, the target range is between -0.5°C and 1.5°C. The RH throughout the post-harvest process should aim to be between 90% and 95%, but at this point in the supply chain, the data was not available. The pallets of grapes are then sent to the dispatch area, ready to be transported from the pack houses, by reefer trucks, to one of two cold storage facilities in the Western Cape, which is about 17 hours of travelling time from the furthest pack house. The reefer containers that the pallets are loaded into are also temperature controlled at temperatures between -0.5°C and 1.5°C. These reefers are not pre-cooled. Although it may seem best to load the palletized grapes into a pre-cooled container, the cold chain has to be broken at this point. When opening and closing a container the temperature within the container changes. If a container is pre- cooled and the doors of the container are open, the outside air would usually be hotter than the inside pre-cooled temperatures. This change in temperature would cause the air within the container to condense and therefore cause container rain (Khan *et al*., 2017:99). This added moisture cannot be measured or controlled, and hence it is dangerous to the quality assurance. Once the palletized grapes are scheduled to be exported, according to the packing program, the grapes are transported via reefer containers to the port of loading (Port of Cape Town). The two cold storage facilities are between 30 to 90 minutes from the Port of Cape Town. The reefer containers are then packed onto a vessel and shipped to the scheduled Port of Destination (POD). Produce is quality checked at the POD and if approved, sent directly to retailers.

This detailed process that takes place from point of harvest to dispatch from the farms can be seen in Figure 2. This figure shows a magnified, simplistic view of a table grape pack house at one of the farms managed by Company Y. Each process can be clearly seen and the flow of the grapes followed through the pack house. Furthermore, Figure 2 also provides details of time taken for each process.

The overall view of the outbound SC process for Company Y is shown in Figure 3. This figure, zooms out and provides detail of the flow of the table grapes from the point of harvest to the end retailer where the grapes will be sold to the final consumer.

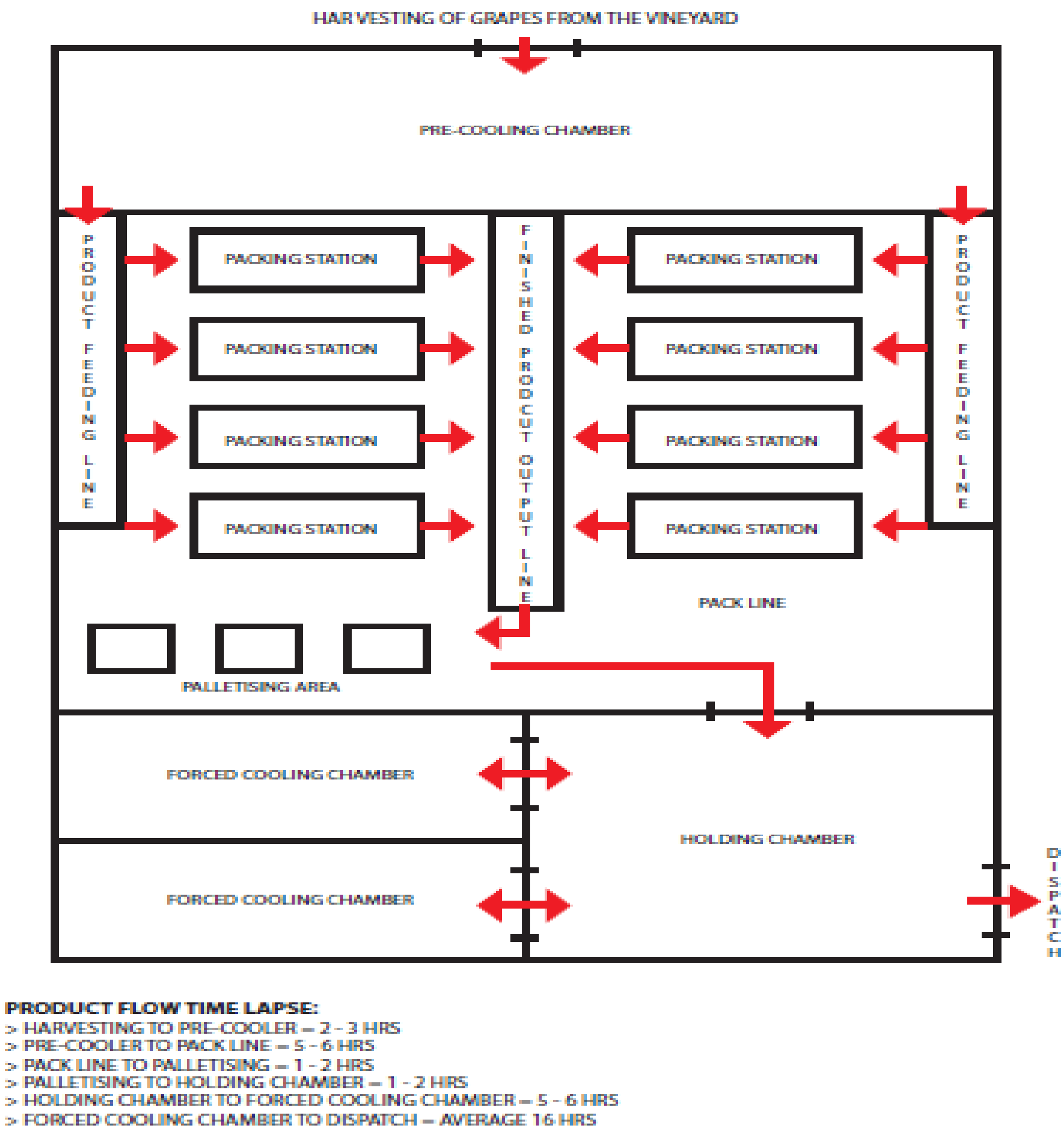

Figure 2: Product Flow from harvest to dispatch at Pack House of Company Y

Source: Logistics Manger from Company Y, 2019

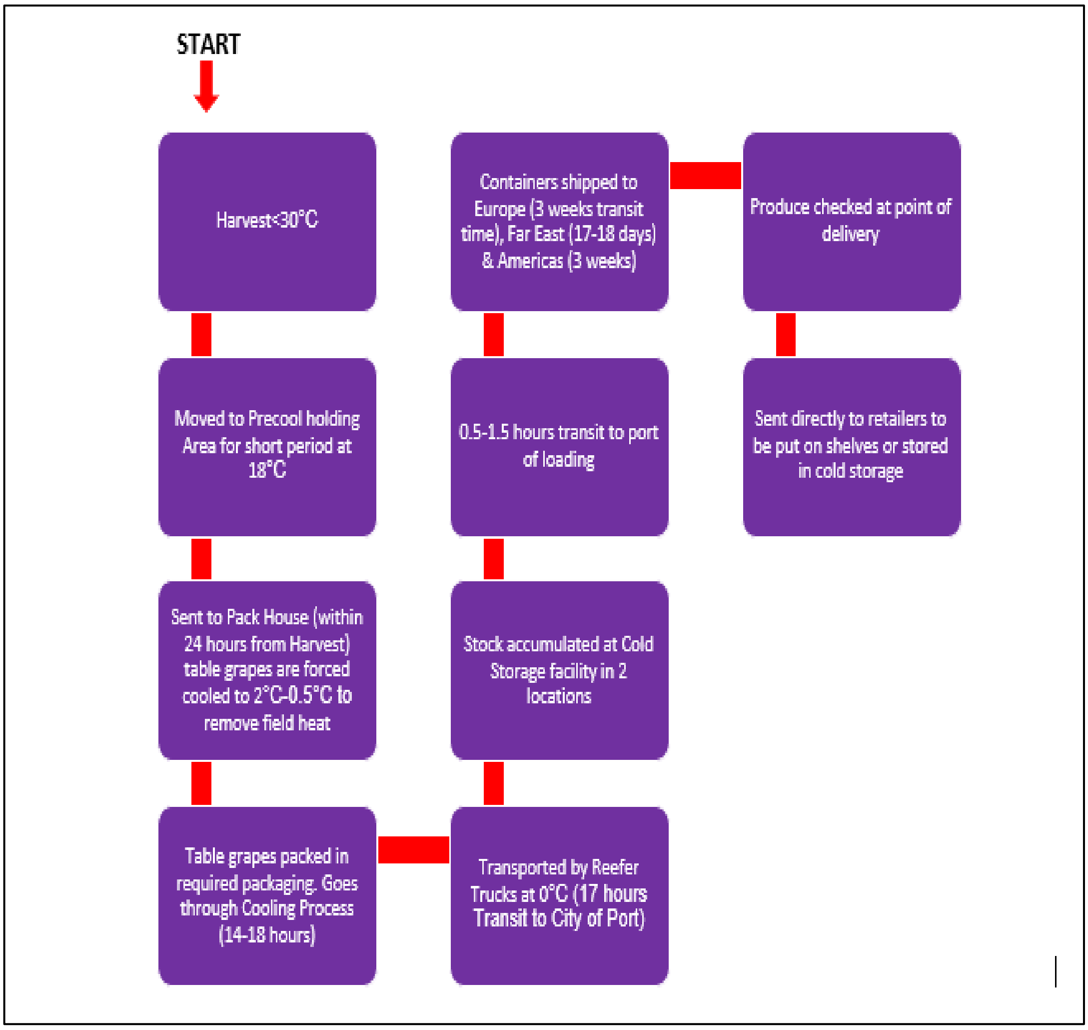

Figure 3: Overall View of the SC Process of Company Y from harvest to retailer

Source: Logistics Manger from Company Y, 2019

2.9 Comparative SC and Logistics studies

In an investigation conducted by Xiao *et al*. (2015), a conventional logistics cold chain for table grapes in China was mapped out. From time of harvest to the consumer took 15 days, transported across 4300km.

At the operational points of the logistics cold chain in their investigation i.e. picking and packing, transport, pre-cooling, storage, loading, refrigerated transportation, loading and point of sale, temperature and humidity were measured and tracked. This was done to determine whether monitoring temperature and humidity could sustain the quality of table grapes. The logistics process of their cold chain is shown in Figure 4.

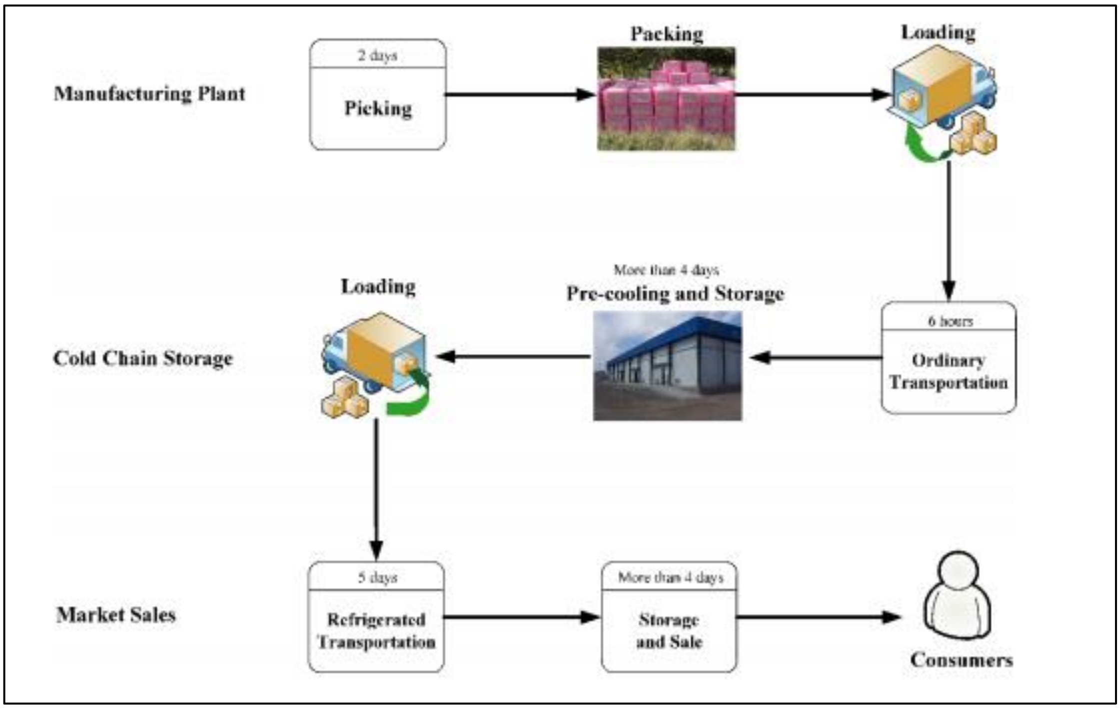

Figure 4: Logistics Process of cold chain of table grapes

Source: Xiao, *et al*, 2015

The curve of the temperature in the study's entire cold chain is visible in Figure 5. The A-B segment is the picking and packing process of the grapes at the farm. The temperature at that stage varied with the ambient temperature, which is approximately 25°C. In this study conducted by Xiao, *et al*, (2015), firmness of the table grapes was identified as the easiest quality feature to evaluate the condition of the grapes throughout the cold chain. Xiao, *et al*, (2015) found in their study that firmness decreases over time during its cold chain logistics processes. They established that the rate of firmness loss differed significantly and concluded the higher the temperature the faster the firmness loss.

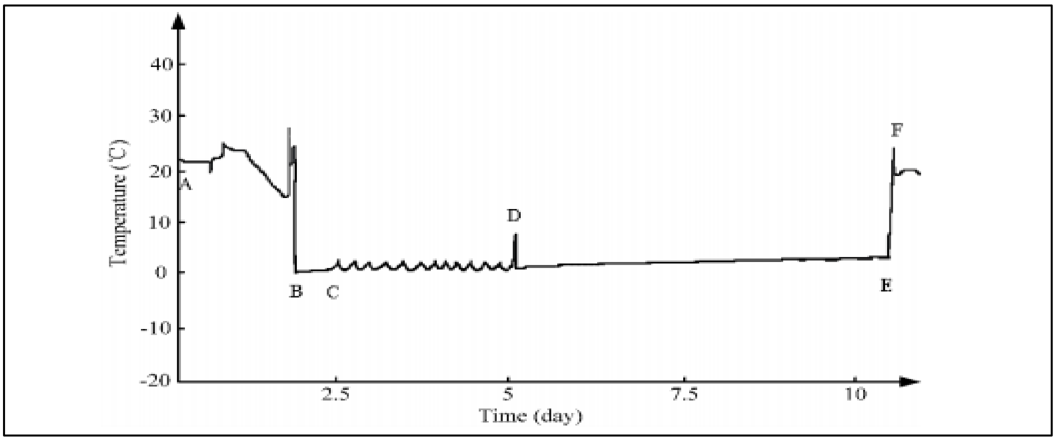

Figure 5: Temperature tracking in the Logistics Cold Chain of table grapes

Source: Xiao, *et al*, 2015

Although there have not been many studies conducted to measure firmness loss, the results of this study do add to the basis of the importance of temperature and time, even at the very beginning of the picking and packing stages.

A study conducted by Wedgwood (2001), showed that pre-cooling grapes to ± 20°C provides the advantage of rapid removal of field heat. By doing this, it causes a higher humidity inside the packaging material that preserves the natural freshness and appearance of the grapes. In addition, it reduces the appearance of dry stems and berry abscission. Wedgwood (2001) goes further to say that by pre-cooling the table grapes to this temperature; it will extend the shelf life and prevent weight loss of the berry.

2.10 Temperature and Humidity

Although there are several environmental factors that affect the quality and safety of table grapes, temperature and relative humidity (RH) are the major determinants (Ngcobo, 2013; Khan *et al*., 2017; Xiao, *et al*, 2015). This is especially experienced during long lead times across the supply chain.

Temperature is the key element that directly affects the respiration concentration of the grapes and the activity of the enzymes (Xiao, *et al*, 2015). Proper temperature management is becoming increasingly important to extend the quality and shelf life of fresh produce across the globe. RH also plays a vital role in sustaining shelf life and high-quality standards. If the RH is too high or too low, this facilitates water loss and therefore diminishes the quality of the grapes.

The recommended storage conditions, which allow fresh deciduous fruit to respond best to, are between 0 and 1 Degree Celsius (°C) (Marsh & Bugusu, 2007: 2). Xiao, *et al*, (2015) and Fourie (2008), also identified the ideal storage temperature of table grapes to be in the range of -1°C to 0°C. Although there may be a slight difference between the storage temperatures, countries across the world have an agreement on the standard conditions that their industries must adhere to in order to be approved for export. According to the PPECB (Cold Management, 2019), for SA exporters, table grapes need to be stored at -0.5°C. This is storage during long transit times.

During temporary storage, a temperature of 0°C to 2°C and a relative humidity of 90%-95% are recommended (Kasmire & Cantwell, 2011). Temperature control is significant and can lead to substantial losses, if controlled poorly (Marsh & Bugusu, 2007: 50). Many fresh produce retailers fail to realise the vast amount of losses that can be prevented through proper cold chain management, as they disregard the incremental losses that they face with fresh produce like table grapes.

2.10.1 Relative Humidity

Relative humidity determines how dry the air really feels. RH is a function of both temperature and how much moisture the air contains. If the temperature is increased while keeping the moisture content constant, the RH decreases and when the temperature is decreased, while keeping the moisture content constant, the RH increases (Grierson & Wardowski, 1978: 21).

2.10.2 The science behind Relative Humidity

Water vapour is the gas phase of water (H_2O). This is when water is no longer in its liquid form, but because of increased temperature and pressure the hydrogen (H) and Oxygen (O) molecules move so rapidly that they no longer cling to each other (liquid or ice), but turn into a gas form.

Condensation is the gas phase of H_2O turning to a liquid phase. For example, when a cold glass of water stands out at room temperature higher than the temperature of the water, the air around the glass condenses and turns to liquid and water droplets form on the outside of the glass.

The more liquid there is, the faster it evaporates. The more water vapour there is, the faster it condenses. At some point, these two processes reach a balance where water vapour condenses just as fast as liquid water evaporates. At this point, the air is said to be “saturated”. This means the air is holding as much water or moisture as it can absorb. This is called an equilibrium. Increasing the temperature speeds up the evaporation and thereby shifts the balance further towards water vapour. This then means that the higher the temperature the more moisture the air must contain before it is saturated (Grierson & Wardowski, 1978: 22).

The relative humidity is a ratio of the amount of water vapour the air is holding as a percentage of what it would be holding if it were saturated, at a certain point in time, at constant temperature.

$$\text{RH (\%)} = \frac{water\ vapour\ in\ the\ air}{water\ vapour\ if\ air\ was\ saturated} \times 100$$

In scientific terms, RH (%) is the ratio of water vapour partial pressure in a gas (**P_w**) to the saturation vapour pressure of water at a certain temperature [**P_{ws} (t)**].

$$\text{RH (\%)} = \frac{\mathbf{Pw}}{\mathbf{Pws(t)}} \times 100$$

RH = Relative Humidity

P_w = Partial pressure of water vapour

Note: The only two properties that can affect a change in P_w is firstly, adding or removing water vapour and secondly, changes in the pressure of the system.

P_{ws} = Saturation vapour pressure

Note: The only property that affects P_{ws} is temperature (t).

t = Temperature

Source: Vaisala, 2012

As explained above, if one increases the temperature, the amount of water vapour the air can hold increases. The RH decreases.

To explain more simply, Figure 6 shows a bucket analogy, which can be used to explain relative humidity. For example, if there is a one gallon bucket and it's filled with one gallon of water. This bucket is at 100% fill. The same amount of water (one gallon) is then poured into a five gallon bucket. This bucket is at a 20% fill (1/5=20%). This would be like if a certain temperature was taken and thereafter the temperature is increased (i.e. increasing the bucket size). By raising the temperature, one goes from 100% to 20%. If the temperature is increased more (the bucket size increases to ten gallons), the fill decreases to 10% (1/10 = 10%). This can be interpreted using RH. As temperature increases (bucket size), relative humidity decreases (fill %) (Vaisala, 2012).

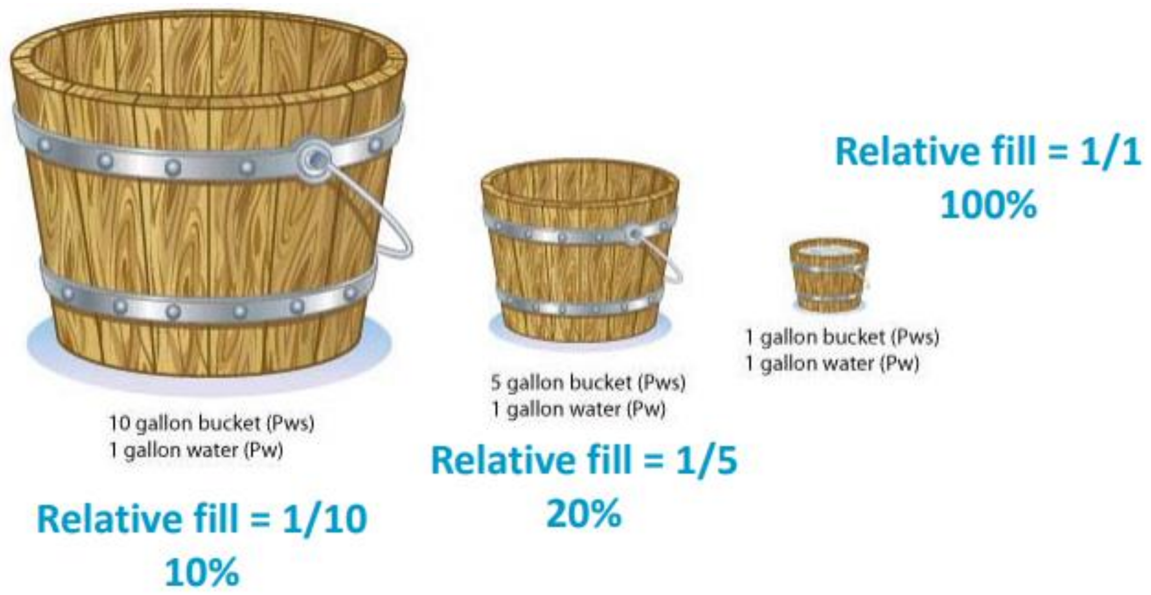

Figure 6: Bucket Analogy explaining relative humidity

Source: Vaisala, 2012

From the data collected and analysed from Company Y, the below temperature and humidity graph (Figure 7) was drawn in Tableau. It can be seen from the graph, that as temperature increases (independent variable), relative humidity decreases (dependent variable). The literature that was reviewed supports the data that was collected.

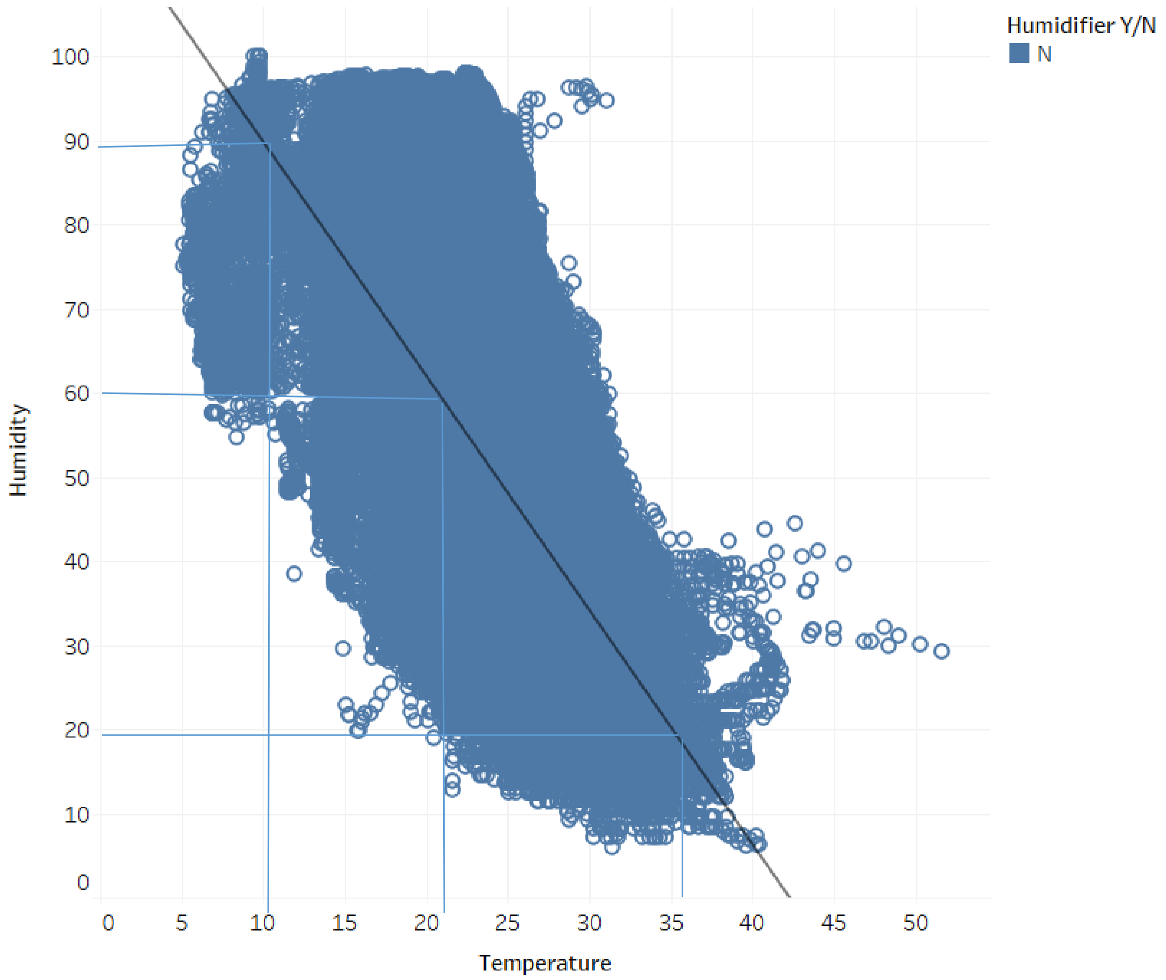

Figure 7: illustrating, as temperature (independent variable) increases, humidity decreases

2.10.3 Dew point

As increasing the temperature decreases RH, decreasing the temperature will increase the RH. If the temperature drops significantly (without changing the water vapour content in the air), eventually 100% RH can be reached. At this point, the water vapour will condense to form dew. The temperature when this happens is called the dew point. This can also be seen on table grapes when water particles (dew) form on the tubes of the grapes (Grierson & Wardowski, 1978: 22).

There are two ways to change relative humidity:

1. Change the amount of water vapours
2. Change the air temperature

Maintaining cold temperatures within the supply chain is critical, as disruptions can cause major quality defects such as moisture loss. This can lead to weight loss, which in turn affects the potential earning income of the product. When the cold storage is disrupted and air enters the cold store, its moisture content drops as the temperature falls below the dew point. This causes condensation to form on the cold surfaces. Condensation can lead to mould growth on the grapes.

The "new" air that enters the storage area warms as it circulates within the area. This reduces the RH. The more the air circulates, the warmer the air becomes. This warm air draws moisture from any surface it can (i.e. table grapes).

By introducing humidifiers into the pack houses, this adds moisture directly into the air. To maintain the temperature and moisture content in the storage area, when "new" air is introduced into the storage area would then not cause moisture to be drawn from the product, but the humidifiers will add the moisture that is lost due to the circulating "new" air and higher temperatures.

Benefits of humidity are (Grierson & Wardowski, 1978: 24):

- Increasing the RH prevents moisture loss.
- The appropriate humidity level may ensure product quality is maintained.
- Freshly harvested appearance can increase product class and hence value.
- Maintained product weight can increase profitability.
- Reduction in waste as products can be stored longer with increased shelf life.

Drawbacks to humidity are (Grierson & Wardowski, 1978: 24):

- Overly humid environments can increase moisture to a point where mould forms.
- Can cause produce to become soft, soggy and eventually lead to rotting.
- If humidity is not maintained at correct levels, this could lead to product loss and therefore profitability.

2.10.4 Structure and design of a humidifier

There are two types of humidifiers, namely cold-water humidifiers and steam humidifiers. To evaporate 1L of water into an atmosphere requires 680W of energy. When steam humidifiers are used, the energy required conventionally comes from the electricity or gas used to boil the water. However, for cold-water humidifiers, the energy required is taken from the air in the form of heat. Therefore, a drop in the air temperature would be seen (Pereira, eSilva, Spagnol & Silveira, 2018).

The structure and design of the humidifier that was used in the pack houses of Company B was designed with specific features such as timers and spray control. The amount of moisture that is distributed around the pack house and on the grapes is essential. As mentioned previously, humidifiers increase the RH in the environment they are placed in. If the humidifier distributes too little or too much moisture, this could still cause quality issues. Low moisture distribution can promote moisture extraction from the table grapes, which will cause the grape to shrivel and be rejected for poor quality. High moisture can cause fungus and other quality issues. In a previous study conducted by Company A, the size of the nozzle and hence moisture distribution, was determined as one of the essential factors to consider (Logistics Manager from Company Y, 2018).

2.10.4.1 Nozzle and moisture distribution

Humidifiers consist of two parts. The first is the humidistat that gives a reading of the current relative humidity in the pack house (Figure 8, left side). The second is the humidifier nozzle that sprays moisture into the air to maintain or increase the relative humidity (Logistics Manager from Company Y, 2019). When the humidistat is set at a certain percentage and that percentage drops, the humidistat will trigger the nozzle (Figure 8, right side) to spray more moisture into the air. This release of added moisture will then bring the relative humidity back up to the percentage it was set at. If the humidistat is set lower, the nozzle will not release any moisture into the atmosphere until it drops below the set percentage where it will trigger the nozzle to spray and release moisture into the air to reach the set humidity (Logistics Manager from Company Y, 2019). The value of the humidifier is increased, because of the humidifier nozzle and the construct of this system to maintain the humidity. This particular nozzle sprays an extremely fine mist into the atmosphere. The moisture cannot be felt on the skin over a period of two to four hours (Logistics Manager from Company Y, 2019).

Figure 8: Humidistat (left) and humidifier nozzle (right)

Source: Logistics Manager from Company Y, 2018

2.11 Quality Control and quality defects

Fresh produce continuously loses water during post-harvest handling (Pereira, *et al.* 2018). Relatively small moisture loss is enough to cause wilting, shrivelling and undesirable texture changes (Kader, 2002). In addition, Pereira, *et al* (2018) illustrate that the percentage loss of fresh weight is used to describe freshness of horticulture products. Hence, the loss of water decreases the products saleable weight and therefore its economic value.

Table grapes' foremost post-harvest quality problems are decay caused by Botrytis Cinerea, rachis desiccation and stem browning caused by water loss (Pereira, *et al.* 2018). Increasing water losses also lead to berry shatter, wilting of the cluster and shrivelling of the berries (Crisosto & Mitchell, 2002). On a few table grape varietals, water losses of 2% to 3%, based on the initial weight, are enough to make stems show symptoms of browning (Crisosto & Mitchell, 2002). However, grape berries do not show symptoms of dehydration until the damage is quite evident in the stems. Losses in weight above 5% are necessary for wrinkles to start to appear in the berry skin (Pereira, *et al.* 2018).

All living things contain water. Agricultural products such as table grapes are living and contain liquid water. When grapes are planted, the plant and its fruit draw water from the soil through its roots. However, when the grapes are harvested, they are cut off from their water source. Liquid water moves across membranes of plant tissue and escapes into the air present in the intercellular spaces as water vapour (Pereira, *et al.* 2018). Keeping in mind, the chemical potential of water in cells compared with that in the adjacent air determines the direction for net water movement occurring at the cell-air interface (Pereira, *et al.* 2018). Thereafter, the plant releases this water vapour into the surrounding atmosphere through a moisture transport known as epidermal transpiration. Plant transpiration is affected by both fruit characteristics (e.g. surface-to-volume ratio, ripening stage) and climatic conditions (e.g. temperature, RH) (Crisosto & Mitchell, 2002).

Principally, the transpiration rate is controlled by the difference in water vapour pressure (WVP). Therefore, considering the air inside the plant material is nearly saturated, the difference in WVP is determined solely by the temperature of the fruit, dry-bulb temperature and the humidity of the air (Pereira, *et al.* 2018). Hence, the environmental conditions are essential in the water loss process of table grapes.

One of the criteria, which quality is measured against, are the grapes physiological features. This is the physical features of the grape, i.e. the colour of the grape, the colour of the stems, whether there is any bruising on the grape etc.

There are various reasons as to how and why table grapes are assessed and valued. A few of the reasons behind how grapes are assessed are the weight of the berries, the physiological features and the taste. As any consumer would know, the higher the quality the higher the cost. The same applies for the quality of fruit and vegetables. Higher "class" produce is sold at a higher price. High quality table grapes are considered to have the following characteristics. Firstly, the grapes need to be firmly attached to stem, secondly, plumpness of the berry must be ensured and lastly, the grapes must be sweet to taste.

In assessing the grapes, the grapes are classed into various categories. To "class" the grapes, growers have identified quality control guidelines to separate the various grapes. Furthermore, depending on the quality or "class" of the grapes, the grapes would have a different value. The grapes are inspected by quality control (QC) officers who grade the grapes.

The officer evaluates according to set standards. The grapes are graded and separated into different scales. The grading of the quality of the table grapes has a scale, also known as a class of 0, 1 and 3. Definitions of the grades are shown in Table 2.

Table 2 Table Grape QC Grading Definitions

GRADE	Description
0	Quality issues – financial impact
1	Good quality
3	Quality issues – no financial impact

Source: Logistics Manager from Company Y, 2018

There were 15 main quality control issues that were identified in this study. Although many of the issues are self-explanatory, there are a few that need further explanation. These are split-condensation, decay, decay-splits, shatter, bruising, decay-condensation, SO_2 burn, low BRIX and browning. The cause of some of these quality control concerns are explained in more detail.

Split-condensation, also known as berry cracking, is one of the most common and most serious quality issues experienced by table grapes. It is a physiological disorder that is generally caused by physical stresses acting on the table grape or occurring because of rainfall, resulting in the skin of the table grape to crack (Ramteke et al, 2017). Other factors that can cause the berry to rupture include, berry temperature, relative humidity, disease and berry ripeness. This is a serious issue for the table grape industry, as it affects grape yield and quality (Gentry & Nelson, 1968).

According to Physiological and molecular plant pathology (Gentry & Nelson, 1968), berry decay is caused by fungi, bacteria or yeast growth, following cold storage, or increased shelf life. The main cause of decay in export grapes is the fungus Botrytis Cinerea (Gentry & Nelson, 1968), also known as grey mould. A confined space with a relatively high humidity and restricting water loss can cause this mould and the berry to decay. These conditions and decay may cause the berries to split. This is also a quality control problem known as Decay-Split.

During transport, table grapes encounter severe water loss and decay (Lichter, Zutahy, Kaplunov & Lurie, 2008). In a study conducted by Lichter *et al.* (2008), pads were positioned over the grapes during transportation to limit or prevent damage. Furthermore, this study also showed sulphur dioxide ($S0_2$) gas was utilized to prevent berry decay, which results from fungal growth within export grape cartons. Gentry & Nelson (1968) identified that it is useful in the industry when the grapes are fumigated with $S0_2$ gas or by packaging a $S0_2$ generating sheet in contact with the grapes. However, if sulphur dioxide levels are too high, bleaching of the grape tissue occurs (Christie, 2001). This bleaching is what is known as $S0_2$ burn.

In order to determine the taste of the grape, the levels of sugar in the berry need to be calculated. Brix measures the table grape berry sugar/acid ratio. Percentage BRIX measures the ripeness of the grape. The standard maturation levels of sugars should lie between 16% and 24% and acid between 0.6% and 1% (Winkler, Cook, Kliewer & Lider, 1974). Low levels of BRIX show that there are low levels of sugar in the berry and the berry will have a tart taste due to the higher level of acidity. High levels of Brix can increase browning in the fresh fruit (Uhlig & Clingeleffer, 1998).

2.11.1 International Standards for export quality grapes

According to the United Nations Economic Commission for Europe (UNECE), the minimum requirements for acceptable produce for export are the following:

Bunches and berries must be <u>sound and clean</u>. If produce is unsuitable for consumption where it is affected by rotting or deterioration, the produce will not meet the criteria to be exported. Clean produce needs to be virtually free of visible foreign matter, pests or damage caused by pests. In addition, produce needs to be free of abnormal external moisture and free of any foreign smell or taste (PPECB, 2019).

Specific minimum requirements for berries are that berries must be intact (attached to the stems), well-formed and normally developed. The development and condition of the grapes must meet the necessary criteria to enable them to withstand handling and transportation. The grapes should also arrive in a satisfactory condition at the place of destination (PPECB, 2019).

2.12 Analysis of the World's Deciduous Fruit Industry

Deciduous fruits refer to fruits that are grown on trees/ plants that shed their leaves and/or other plant structures seasonally. The fruit tree sheds its leaves after flowering or fruit ripen (Deciduous, 2017). Some deciduous fruit examples are table grapes, apricots, peaches and nectarines.

Figure 9 shows the global production and consumption of table grapes for the years 2011/2012 to 2016/2017. Figure 9 shows that there was a steady increase in the global production and consumption of table grapes from 2011/2012 to 2014/2015. Production decreased slightly in 2015/2016 and increased again in the 2016/2017 season. In the 2016/2017 season, there

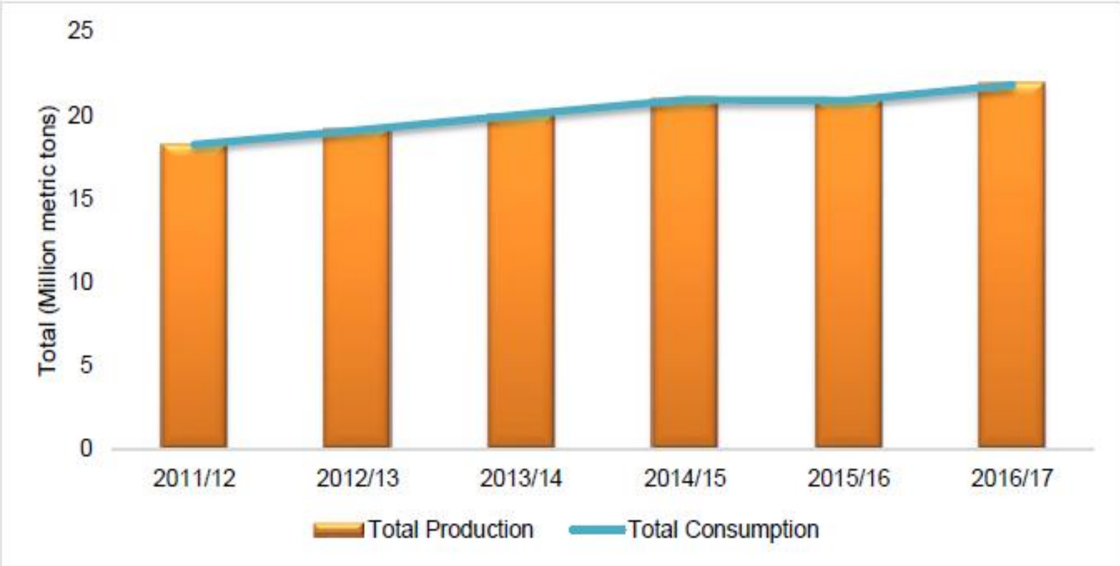

Figure 9: Global production and consumption of Table Grapes

Source: United States Department of Agriculture, 2017

were over twenty million metric tons of table grapes produced and consumed around the globe.

Figure 10 shows the highest producing countries of table grapes across the globe. From this graph, it can be established that of the top ten countries producing table grapes, South Africa is ranked tenth. South Africa must compete with number one ranking, China that produced over ten million metric tons of table grapes in 2017. That is almost half of what was produced and consumed worldwide in 2017(refer to Figure 10).

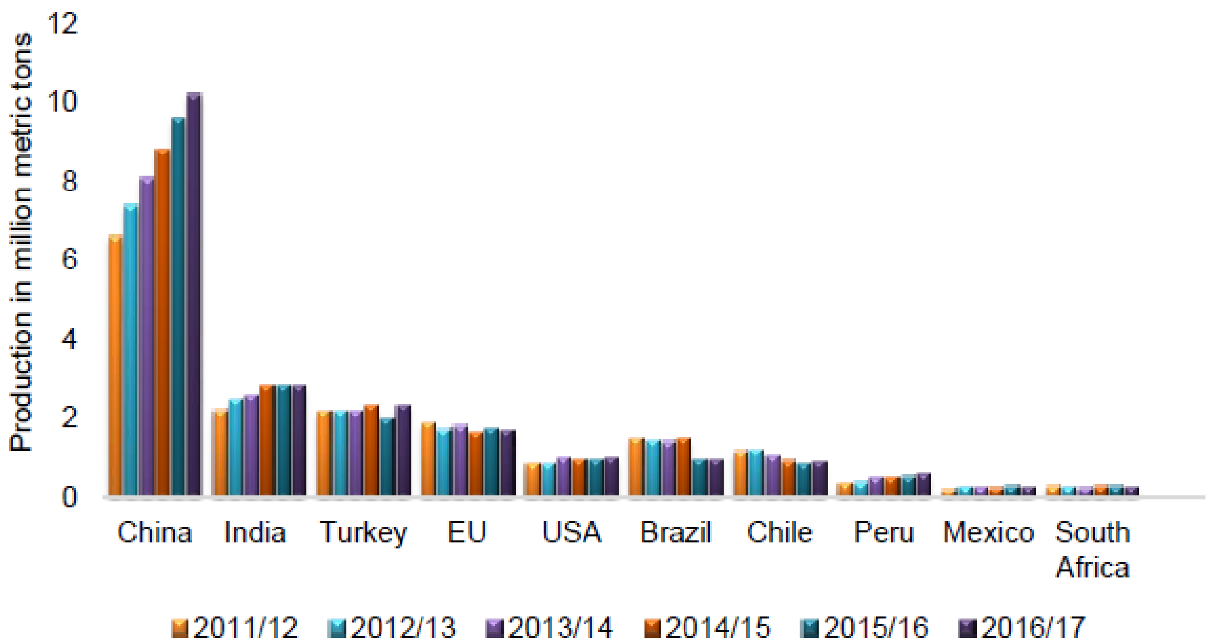

Figure 10: Highest global Producing countries of Table Grapes for years 2011/12-2016/17

Source: United States Department of Agriculture, 2017

Furthermore, Figure 10 depicts that the top two producing countries experienced noticeable growth in production over the years. South Africa, however, shows very little growth from 2013/2014 to 2014/2015 and production decreased in the 2016/2017 season. This was due to the drought that the Western Cape was facing at the time.

The international fruit market is becoming increasingly competitive and is putting pressure on exporters to improve the quality and taste of fruit that they produce (Ntombela & Moobi, 2013). Therefore, it is valuable for South African exporters to investigate ways into increasing the quality of table grapes to become more competitive.

2.12.1 Table Grapes in South Africa

South Africa is a substantial contributor to the world's fresh fruit industry. It is known for its diverse weather and climatic conditions. This factor is one of the major reasons for its wide variety of fresh fruit produce. The country exports subtropical, citrus and deciduous fruit types. This study focuses on deciduous fruits, specifically the table grape.

In the year 1652, Jan van Riebeeck planted the first grapes in the Western Cape's, Cape of Good Hope and pressed the first 'Hanepoot' and 'Muscadel' varieties in February 1659. All the early rulers were mainly interested in wine production and it was not until 1886 that the first attempt to export table grapes to the United Kingdom was undertaken (Fresh Plaza, 2019).

Today, South Africa is the third largest producer of table grapes in the Southern Hemisphere following after Chile and Peru. On a global scale, South Africa is the tenth largest producer and the fifth largest exporter of table grapes (Fresh Plaza, 2019).

Due to its five production regions, South Africa can supply the international and domestic markets from November to April. Only a small portion of total production is designated for the domestic market. To meet out-of-season demand (June to mid-October), South Africa imports more than five thousand tonnes of grapes annually from Israel, Egypt and Spain (Fresh Plaza, 2019).

South Africa's cultivar profile has changed in recent years to reflect consumers' preference for seedless grapes. Some of the top cultivars exported to more than sixty countries are 'Crimson Seedless', 'Prime Seedless', 'Thomson Seedless', 'Red Globe' and 'Flame Seedless'.

Aside from figs, table grapes are regarded as the most profitable (per kilogram) fresh fruit to market. However, production costs are high as grapes are a labour intensive crop and vulnerable to many pests and pre- and post-harvest diseases (Fresh Plaza, 2019).

The fresh fruit industry is important to South Africa as it contributes significantly to the economy of South Africa. In addition, the South African fresh fruit industry is of great economic importance to the country as the industry employs approximately 460 000 people (Davids, 2013). Overall, the table grape industry specifically, exported over seventy million cartons of grapes in the 2016/2017 season (Bestbier, 2017). This, compared to China's ten million metric tons of grapes, shows that there is great room for improvement. The industry employs both permanent and seasonal workers, which also indirectly contributes to the growth of the country. By providing efficient and effective logistics in this industry, it not only affects the local consumers and businesses, but it ensures that South Africa has influence in the world market. Internationally, table grapes are one of the largest traded fruit types in the world. South Africa is ranked tenth amongst the biggest suppliers in global production of table grapes (USDA, 2016).

The 2016/2017 season was a successful season for the South African table grape industry, as over sixty-seven million cartons of grapes were approved and exported from domestic producers. This is a 13.8% increase in volume from the last biggest harvest in the 2014/2015 season (Bestbier, 2017). However, in the last five years there has been minor growth with a 4.3% average increase in volume (Bestbier, 2017). This could be due to the severe drought that most provinces in South Africa faced.

Of South Africa's international markets, Europe is its largest stakeholder. Over half of what the South African table grape industry produces, is sold in the European market (Bestbier, 2017). This means that the standard of grapes that South Africa needs to produce and distribute, must meet first world standards. The quality in which the table grapes arrive at international ports is vital and therefore shelf life and quality of the grapes at harvest are extremely important. Many South African table grape businesses and other dependents benefit from the strong international currencies, as it not only sustains the South African economy, but these businesses and their workers.

Within the table grape market, South Africa is ranked lower than many other industry giants such as China, India, Turkey and a few others (USDA. 2016). This may be due to planting acreage, cheaper labour, better technology or efficient processing, but one way South Africa could be more competitive would be to improve the quality of grapes supplied. A possible solution to improve the quality of table grapes supplied would be to investigate the entire cold chain, post-harvest and focus on introducing humidifiers in South African table grape pack houses.

According to a report by the Food and Agricultural Organization (FAO, 2016), grapes are one of the fruits with the highest input of technology (cooling, packing, sulfureting, cold storage) and practices (manual labour). Owing to this fact, it is the fruit crop with the highest total value of production in the world as shown in Figure 11.

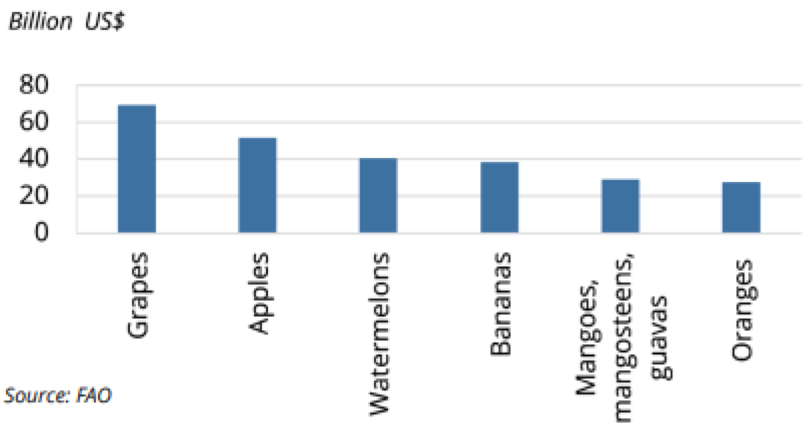

Figure 11: Value of agricultural production of top fruit crops of 2014

Source: (FAO, 2016)

The capital expenditure of producing table grapes in SA is high and these costs have increased steadily over the years. Table 3 shows the average production costs South African farmers and manufacturers incur per hectare per year. In five years (from 2013 to 2017) costs have risen by 42% (total expenditure in 2013 was equivalent to R167 710.00/hectare and total expenditure in 2017 was equivalent to R238 448.00/hectare). To install humidifiers would also be a significant expense for farmers and therefore thorough research needs to be done to validate the use of humidifiers and their benefit to the table grape industry.

Table 3: Production Cost for Table Grape Farms ZAR/HA

COST STRUCTURE		2017		2016		2015		2014		2013
DIRECT PRODUCTION COST										
FERTILISER & ORGANIC MATERIAL	R	9,985	R	9,367	R	8,543	R	7,374	R	6,099
PESTICIDE & HERBICIDE CONTROL	R	23,049	R	17,347	R	19,384	R	14,682	R	10,630
SUPERVISION, PERMANENT, SEASONAL & CONTRACT LABOUR	R	134,404	R	114,803	R	118,072	R	117,918	R	96,242
FUEL, OIL, REPAIRS, PARTS AND MAINTENANCE	R	20,141	R	18,593	R	20,940	R	20,040	R	17,628
LICENCES & INSURANCE	R	1,636	R	1,023	R	701	R	253	R	1,411
HIRED TRANSPORT	R	1,657	R	1,003	R	1,079	R	479	R	566
ELECTRICITY	R	9,305	R	9,411	R	8,253	R	7,343	R	7,465
WATER	R	1,670	R	1,387	R	1,137	R	1,061	R	1,167
LAND, PROPERTY, MUNICIPAL TAXES, ADMINISTRATION AND MISCELLANEOUS	R	6,790	R	6,795	R	6,344	R	5,502	R	3,906
TOTAL CASH EXPENDITURE	R	208,637	R	179,729	R	184,453	R	174,652	R	145,114
DEPRECIATION	R	29,811	R	28,220	R	25,221	R	23,943	R	22,596
TOTAL EXPENDITURE	**R**	**238,448**	**R**	**207,949**	**R**	**209,674**	**R**	**198,595**	**R**	**167,710**

Source: Bestbier, 2018

When Company Y identified the problem of brown stems on their grapes, it prompted them to investigate whether this would happen if the table grapes were stored, packaged and transported in the best way possible. Company X believes that a possible treatment for lengthening the shelf life and improving the quality of table grapes is using humidifiers in pack houses at the post-harvest stage.

Table grapes, like many other fruits in the South African fruit industry have experienced substantial growth in value over the last few years, as consumers both locally and internationally want to enjoy fruit all year round. As the value in this industry increased, South African farmers are wanting to produce higher volumes to increase domestic and international sales. This industry would have the potential to grow even further if its grapes can retain high levels of quality for a long period of time to satisfy international markets.

2.13 Climate/ Temperature Requirements

Goedhals-Gerber, Freiboth, Haasbroek and Van Dyk (2015) state that the most important factor in post-harvest management is temperature management. Even slight variations in temperature can have a major impact on the shelf life of fresh produce and its value.

As exported grapes from South Africa are transported across the world via reefer containers, the temperature of the fruit has to be maintained from the farms. As stated by Goedhals-Gerber *et al* (2015), there is a misbelief that reefer containers have the ability to cool fruit down; however, these containers are designed to maintain the temperature within a predetermined range and not to cool it down. This, therefore, implies that fresh produce (in this case table grapes) must be brought down to the required temperature before being loaded into these containers (Goedhals-Gerber *et al*., 2015).

Table grapes usually thrive in a hot, dry climates. They require low humidity, hot days and cool nights. These kinds of growing conditions usually produce the best quality grapes (DAFF, 2012). Although DAFF (2012) recommends low humidity to produce the best quality grapes, this is recommended as best growing conditions and not conditions post-harvest. For the fruit and the vegetative part of the plant to mature, the cultivation season needs to be long enough to allow this to happen.

The reason for the blossoming table grape industry in SA is mainly due to SA's climatic conditions. The "ideal" climate for table grapes to be cultivated in are Mediterranean and subtropical regions. These are regions that experience mild, rainy winters and hot, dry summers (DAFF, 2012). SA is known for its warm temperatures and in Provinces such as the Western Cape, Northern Cape and a few others, perfect weather conditions, which are suitable for table grape growth, are experienced. There are five main production regions in South Africa, namely the Northern Province, Berg River, Hex River Valley, Olifants River and the Orange River. The cultivation season in SA runs from the month of April to harvest season in November (DAFF, 2012).

To prevent various grape diseases there needs to be as little rain as possible (DAFF, 2012). However, drought concerns, which the Western Cape and Northern Cape Provinces of South Africa have recently faced, have shown that this too can have negative implications on the percentage yield in this industry.

2.14 Current international best practice

Grapes are one of the world's most widespread produced fruit crops. There are approximately seventy-five million tonnes produced each year although almost 50% of grapes are used to make wine. Only one third of what is produced is consumed as fresh fruit, while the rest is used for juices or stored as raisins (FOA, 2016).

There is currently very limited information on what major role players are practicing in the industry, post-harvest. However, some of the recent entries and biggest players in the table grape market, India and China, are beginning to share some insight into their harvest and post-harvest methods. India, for example, follow the procedure of not harvesting grapes after 10am in the morning. If it rains prior to harvest, fruit is not picked for three to four days, as this free moisture on the berries may lead to fungal infections. Clusters of grapes should not be held without wearing rubber gloves while harvesting, trimming or cleaning. This is done to not remove the fine waxy coating called “bloom” from the berry surface. The harvested grapes are placed in plastic crates lined with bubble sheets used as cushioning. The crates are left on newspapers that are on the ground and left in the shade. The newspaper is used to avoid contamination with vineyard dust on the ground. The grapes are transported to the pre-cooling area within 4 to 6 hours of harvest. The temperature of the harvested grapes are brought down to less than 4°C within six to eight hours in the pre-cooling chamber. The temperature in the pack houses are maintained at 18°C to 20°C. The grapes are packaged and moved to cold storage rooms where the temperature and humidity are maintained at 0°C ± 0.0°C and 93% ± 2% respectively. Freezing injury to berries, pedicels and rachis occur at -2 °C (Adsule, Yadav, Satisha, Sharma, & Upadhaya, 2013).

In recent years, the Port of Cape Town, South Africa have implemented changes to the fruit export supply chain. These include the implementation of the terminal operating system known as the Synchronous Planning and Real-time Control System (SPARCS) that was developed by NAVIS and the Reefer Container Monitoring System, known as the Refcon system (Goedhals-Gerber et al., 2015). “The Refcon reefer monitoring system is a computer program which allows complete visibility of the status of reefer containers in the stack yard of a port” (Goedhals-Gerber et al., 2015).

One of the latest technologies that a German company (Osram Opto Semiconductors) has introduced to consumers is the use of smartphones to analyse ingredients, nutritional content and freshness of food in grocery stores. The development in broadband near infrared LEDs (NIREDs) and mobile spectroscopy has made technologies like this possible. Furthermore, by the use of near infrared spectroscopy can help farmers to implement smart farming solutions where farmers can be provided with instant, reliable information about the sugar, water, protein and fat content of produce (Macnamara, 2019). The use of such technologies can be implemented throughout the supply chain to ensure that the shelf life of fresh produce can be monitored.

2.15 Best Practice in SA

In 2013, a study conducted on fresh table grapes, by Stellenbosch University researchers developed a guide on the good cold chain practice for the export of table grapes from South Africa. The guide clearly and simply guides farmers, workers or any other stakeholder on the dos and don’ts of the good cold chain practice of table grapes. The guide also focused on maintaining an optimum temperature throughout each process of the supply chain (Haasbroek, 2013). The guide is tabulated in Table 4.

Table 4: Good cold chain practice guide dos and don'ts

Step in the Supply Chain	**DOS**	**DON'TS**
Harvesting on the farm	Fruit should be harvested in ambient temperatures below 30°C. However, pulp temperatures should be below 25°C.	Fruit should not be harvested in ambient temperatures that are above 30°C.
	Fruit should be harvested during early morning hours when the outside temperature is cool.	If ambient temperatures exceed 30°C, harvesting should stop.
	Fruit should be transported via covered units as soon as it has been harvested.	Fruit should not be left standing in the vineyard once it has been picked.
Pre-cooling unit	Fruit should be offloaded in a shaded, cool area.	Fruit should not be offloaded where it is exposed to direct heat/sunlight.
	Fruit should be offloaded and placed in a precooler within 30 minutes of arriving at the pack house.	Delay in offloading the fruit at a precooler will lead to dry stems.
	Fans should be at each end of the pre-cooling unit to ensure consistency in temperature throughout the room.	Fans only on one side of the pre-cooling unit, which can cause variances in temperature within the room.
	Temperature within the unit should be above dew point (usually between 15°C and 18°C). A permanent thermometer is vital.	Precooler should not be warmer than 18°C.
	Maintain humidity levels between 85% and 95% by making use of wet walls or fogging systems.	Humidity levels must be monitored and must not drop too low or it will result in shrivelled fruit.
The pack house	According to protocols, pack houses should be maintained at temperatures between 18°C and 25°C. Having a permanent thermometer is vital.	Pack houses should not be warmer than 25°C.
	Maintain humidity levels between 85% and 95% by making use of wet walls or fogging systems.	Humidity levels must be monitored and must not drop too low or it will result in shrivelled fruit.
	Pack houses with insulated roofs can help keep the temperatures inside low.	Pack houses without insulated roofs can cause increased temperatures.
	Lighting must be sufficient, but should not cause substantial effects on the temperature of the fruit.	Lighting inside a pack house can cause increased fruit temperatures if they are too bright or situated very close to the working stations.
	In coming fruit from the pack house should be at temperatures inside protocol.	In coming fruit from the pack house should not have high pulp temperatures.

	Temperature monitors should be inserted in the centre of pallets while pallets are being stacked in the pack house.	Temperature monitors should not be inserted into pallets minutes before the fruit is loaded into a container.
The cold store	Know that the optimum fruit pulp temperature for table grapes is -0.5°C.	Should not be uncertain about the optimum temperature that each fruit should be cooled down to.
	Doors of cold stores should only be opened when absolutely necessary.	Doors of cold stores should not be left open longer than required.
	Use strip curtains at cold store doors to prevent or limit warm air from entering the room.	Opening cold store doors without strip curtains allow warm air in.
	Maintain humidity levels between 85% and 95% by making use of wet walls or fogging systems.	Neglecting to monitor humidity levels results in shrivelled fruit.
Loading of pallets into containers	Use staging rooms for the loading process to complete loading as soon as possible.	Delayed loading of containers occurs due to misplaced pallets.
	Fruit must remain in cold storage until the fruit pulp temperatures meet PPECB requirements (-0.5°C for table grapes).	Neglecting PPECB protocols when loading of pallets into a container.
	Using airlock loading bays is ideal.	Loading pallets outdoors in warm temperatures.
Cold Store to Stack	All trucks waiting in queues at the port should have reefer containers plugged into a genset and the genset must be switched on.	Trucks waiting in long queues at the port without gensets or gensets that are switched off.
	All containers must be fitted with the necessary and automated monitoring system to ensure the containers temperature is monitored 24 hours a day.	Manually monitored reefer containers if not fitted with the necessary modem to monitor temperature.
Stack to vessel in port (Quayside)	Containers should enter the port at specified times when the stacks are open to ensure a place in the reefer stack.	Entering the port once the stack has been closed should be avoided.

Source: Haasbroek, 2013

2.16 Previous studies

This section gives a brief overview of studies that have been conducted previously and that relate to this thesis. Earlier in this study, various other universal studies relating to temperature control and the cold chain, were referenced. This section focuses on previous application of humidifiers in a South African table grape farm and studies that were conducted by Stellenbosch University.

In an article posted by Jansen (2017), Company X implemented humidifiers into its holding rooms as a post-harvest treatment. In 2015, Company X brought a change to its table grape holding rooms, whereby it implemented four units of Miatech Aquaroom 4S humidification systems. This was done to increase the holding room's relative humidity to 95%, where the grapes were held at 20°C. The reason for holding the grapes at this high relative humidity was said to reduce the humidity gradient between the fruit and its surrounding atmosphere (Jansen, 2017). If the surrounding atmosphere is drier than the fruit, which is usually the case in South Africa, moisture will be drawn along the gradient, out of the grapes and into the atmosphere. This initiates post-harvest decay (Jansen, 2017). Company X harvests its grapes and gets it into the holding rooms within twelve to twenty minutes to begin the post-harvest treatment as soon as possible. Due to the high relative humidity of the storage rooms, extraneous vegetative parts can be pruned from the bunches of grapes, the previous night and will not cause the stems to dry out. Packing can begin first thing in the morning and will reduce time lost (Jansen, 2017). The current procedure of Company Y is to harvest the grapes, store for a short period of time in the holding area and to pack within six to eight hours. This process is followed to reduce the risk of browning stems and fruit deterioration (Logistics manager from Company Y, 2019). The owner of Company X explains, "The secret is to cut the grapes as soon as possible. In the past grapes started drying out in the holding rooms, but now grapes can be kept there for longer and with better results". Furthermore, the owner goes on to say that when stems remain green, there is no chance of infection developing between the berry and the stem (Jansen, 2017). Two years after the implementation of the humidification system, Company X claims that its quality claims had dropped significantly. Company X supplies Woolworths, one of South Africa's biggest retail food chains, and in 2017 said that they received no quality claims from the retailer that year (Jansen, 2017).

2.17 Global Warming and its effects on yield and quality over time

Global warming is caused by the increased Carbon Dioxide (CO_2) levels in the atmosphere. CO_2 absorbs heat from the environment more quickly than any other gases and through the ages as more people populate the planet and exhale CO_2, as more motor vehicles and industries burn fuels that release CO_2, the temperatures on planet Earth increases. However, water vapour has an even greater effect on global warming than CO_2. Its concentration in the atmosphere is much higher than CO_2 and contributes about 60% to the global warming effect (Letcher, 2019:4). The amount of water vapour is controlled by the temperature. CO_2 increases the temperature in the atmosphere slightly, but with this increase in temperature more water from the ocean is evaporated, thus, increasing the water vapour in the air (Letcher, 2019:4). Water vapour has a direct influence on humidity and the higher the concentration of water vapour in the atmosphere, the higher the level of humidity. As a result of global warming, the climate's temperatures are changing across the globe.

As a developing country, SA is especially vulnerable to the effects of climate change. Responding to climate change with an increase in economic growth and a sustainable use of environmental resources is becoming a greater challenge, especially for impacted industries such as the agricultural industry (Climate Change, 2016).

For South Africa, water is the primary resource through which the impacts of climate change are being felt (Climate Change, 2016). Exacerbated climate variability and climatic extremes are not only impacting water availability, but also water quality. Changes in rainfall patterns, with more acute storms, floods and droughts; changes in soil moisture and runoff; and the effects of inflated evaporation and changing temperatures on aquatic systems. South Africa has faced a serious drought since 2015, with corresponding crop losses, water restrictions and impacts on food and water security (Climate Change, 2016).

In South Africa, there are several main table grape growing regions. Figure 12 highlights these regions. In this study, the focus area is the Northern Cape.

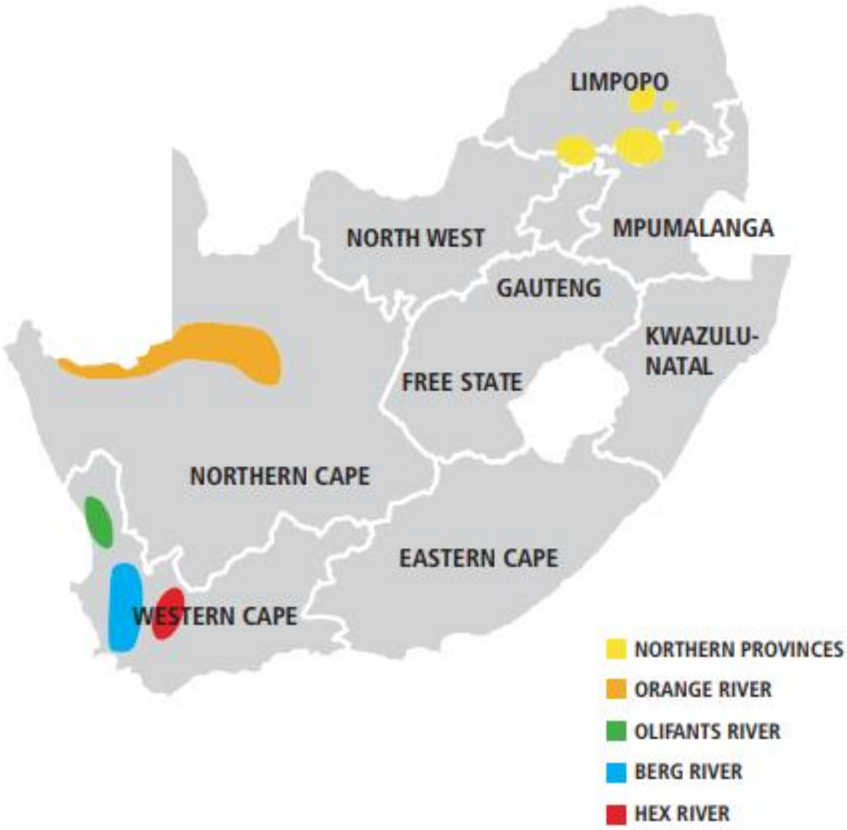

Figure 12: Table Grape growing regions in South Africa

Source: Lombardt, 2018

2.17.1 Drought in South Africa

The Northern and Western Cape provinces of South Africa are known to experience rainfall during their winter season. In 2015, 2016 and 2017, these provinces faced serious water shortages due to poor rainfall during the winter season. In 2018, the Western Cape faced a drought disaster in the first few months of the year, which are crucial harvesting months for table grapes. However, the disaster appeased in the winter season, bringing well needed rainfall.

The demand for water in these provinces is steadily increasing due to the growing population and increasing economic needs of the country. Water is not only required for daily personal use, but is also a main resource for the agricultural and manufacturing industries.

2.17.1.1 Drought & its effects on yield in the Northern and Western Cape Provinces

As previously stated, the prime seedless and the flame seedless varieties belong to the white and red seedless cultivars. In its' latest report, the South African Table Grape Industry (SATI) showed their 5-year regional intake across their main cultivar groups. The regional intake represents the produce that was inspected from the various regions and were passed for export. This is shown in Table 5.

Table 5: SA's 5-year regional intake (4.5kg equivalent cartons)

REGION NAME	CULTIVAR GROUP	2017/2018	2016/2017	2015/2016	2014/2015	2013/2014
NORTHERN PROVINCES	Black Seeded	299 459	364 577	381 919	378 032	400 312
	Black Seedless	456 737	386 988	283 863	314 536	314 088
	Experimental	11 528	0	7 000	1 333	182 823
	Mixed	132 089	178 905	99 551	41 032	73 010
	Red Seeded	277 836	364 584	362 856	605 540	592 959
	Red Seedless	4 053 498	2 868 143	2 189 378	1 754 278	1 426 018
	White Seeded	0	1 400	3 736	43	13 163
	White Seedless	1 597 615	1 373 188	1 402 628	1 415 931	1 081 226
TOTAL		6 828 762	5 537 784	4 730 931	4 510 726	4 083 599
ORANGE RIVER	Black Seeded	26 430	36 130	31 429	52 228	63 643
	Black Seedless	2 101 921	2 204 231	1 620 429	1 216 134	993 865
	Experimental	35 800	278	3 167	14 828	181 296
	Mixed	230 500	180 962	196 268	126 509	90 057
	Red Seeded	400 898	421 896	407 496	612 562	546 424
	Red Seedless	3 892 202	4 010 491	3 248 134	2 748 330	2 136 649
	White Seeded	87 174	222 484	259 520	370 900	453 647
	White Seedless	12 240 717	13 456 043	12 876 163	12 545 235	10 653 380
TOTAL		19 015 641	20 532 515	18 642 606	17 686 725	15 118 961
OLIFANTS RIVER	Black Seeded Grapes	15 646	55 670	126 357	191 770	186 442
	Black Seedless Grapes	489 158	700 010	501 897	560 846	448 460
	Experimental Grapes	6 038	0	2 863	90	65 508
	Mixed Grapes	27 146	33 991	22 787	6 237	127
	Red Seeded Grapes	177 304	574 054	400 831	615 803	648 129
	Red Seedless Grapes	1 552 449	1 927 671	1 445 795	1 636 387	1 202 854
	White Seeded Grapes	3 450	9 782	12 171	22 048	18 209
	White Seedless Grapes	531 246	666 894	644 358	755 106	551 327
TOTAL		2 802 436	3 968 073	3 157 059	3 788 287	3 121 056
BERG RIVER	Black Seeded	724 725	970 095	1 117 385	1 434 440	1 321 869
	Black Seedless	2 365 703	2 665 228	1 776 749	1 424 283	1 079 942
	Experimental	169 351	1 867	14 181	20 677	567 624
	Mixed	62 391	83 635	69 693	49 908	34 471
	Red Seeded	1 118 827	2 027 272	1 466 667	1 831 673	2 190 763
	Red Seedless	5 688 476	5 909 793	4 581 789	4 315 897	2 806 528
	White Seeded	634 555	860 588	863 972	986 941	1 083 086
	White Seedless	2 288 588	2 907 697	2 709 290	2 998 630	2 294 719
TOTAL		13 052 616	15 426 175	12 599 726	13 062 449	11 379 002
HEX RIVER	Black Seeded	608 347	892 763	1 124 143	1 714 402	1 712 921
	Black Seedless	2 752 631	3 562 003	2 910 874	2 829 166	1 990 439
	Experimental	112 760	3 323	5 697	20 936	335 795
	Mixed	179 412	459 896	73 472	144 666	77 474
	Red Seeded	997 676	1 271 422	1 248 029	1 601 957	1 735 531
	Red Seedless	13 849 001	13 260 373	10 540 278	9 905 126	7 131 282
	White Seeded	237 334	791 459	954 238	1 610 449	1 868 045
	White Seedless	1 628 134	1 869 373	1 992 487	2 504 389	1 994 709

Source: Lombardt, 2018

Figure 13 depicts the white seedless intake quantities from the years 2013/2014 to 2017/2018. Table grapes are grown and harvested from one year to the next and therefore the yearly seasons do not reflect one full year, but a part of two consecutive years (i.e. 2013/2014). From the 2013/2014 season, there was an increase in intake across all regions. The Berg River was the only region to experience a drop in their 2014/2015 season intake, but recovered in the 2016/2017 season, which showed growth or no movement across the various other regions. The 2017/2018 season brought about a decrease in intake across all regions except in the Northern Province. As referenced earlier, the Northern and Western Cape provinces were declared drought disaster areas at the beginning of 2018. The effects of the drought can be seen in the country's white seedless grape intake in the 2017/2018 season.

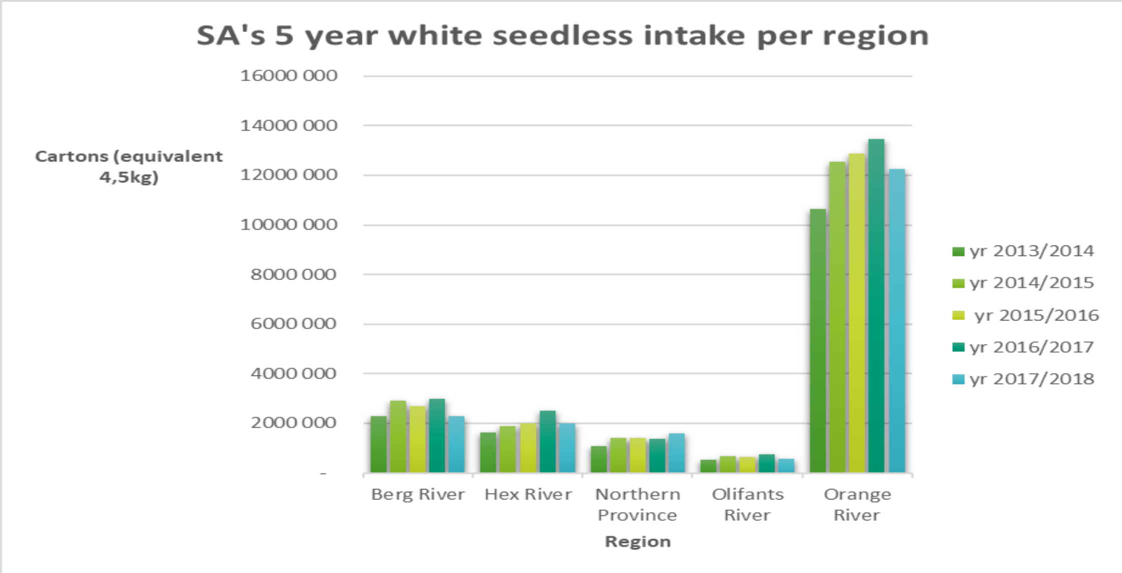

Figure 13: Clustered chart showing SA's white seedless grape per region over the past 5 years

Source: Lombardt, 2018

The same can be seen for the red seedless varieties in the 2017/2018 season in Figure 14. The only region to experience growth in intake was the Northern Province, whereas the regions situated in the Northern and Western Cape all had lower intake values.

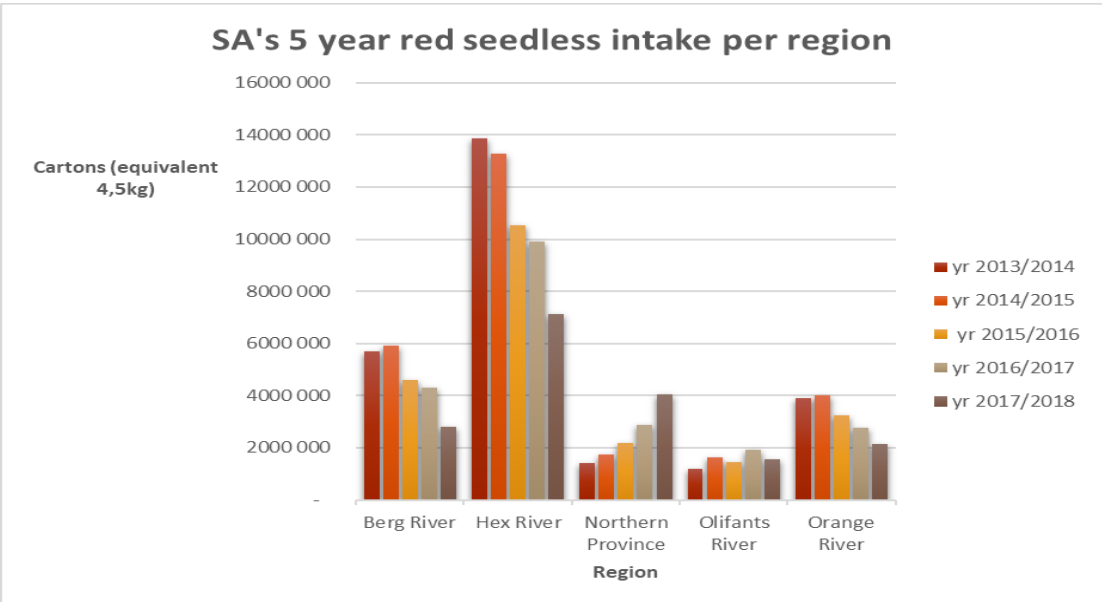

Figure 14: Clustered chart showing SA's red seedless grape per region over the past 5 years

Source: Lombardt, 2018

Table 6 shows the quantity of cartons that were approved for export, specifically for Prime and Flame seedless grapes. Table 7 shows a percentage drop in the intake from 24% and 29% in 2014/2015 to -15% and -20% in the 2017/2018 season. These two varieties are amongst the highest demanded grapes in the market and this table shows the effects that the drought in the Northern and Western Cape of South Africa, had on the industry.

Table 6: SA's five-year export of the 2017/2018 top 20 cultivars (4.5kg equivalent cartons)

CULTIVAR	2013/2014	2014/2015	2015/2016	2016/2017	2017/2018
Crimson Seedless	8 948 985	10 480 704	10 935 948	12 457 844	13 089 359
Prime	5 670 998	7 048 640	7 321 330	7 368 474	6 277 968
Thompson Seedless	4 845 413	5 685 990	4 584 681	4 719 094	3 988 364
Flame Seedless	3 357 505	4 319 214	4 243 418	3 479 040	2 793 219
Sugranineteen (Scarlotta Seedless®)	621 134	1 385 297	1 533 604	2 612 051	2 850 640
Sugraone (Superior Seedless®)	3 137 593	4 203 884	3 615 032	3 137 782	3 668 364
Tawny Seedless	1 467	25 502	407 241	1 538 776	2 421 082
Redglobe	5 512 613	4 621 778	3 241 393	4 792 971	2 259 028
Sugrathirteen (Midnight Beauty®)	1 576 922	2 098 524	2 183 407	2 738 668	2 304 725
Blagratwo (Melody™)	198 307	381 008	949 245	1 435 154	1 667 582
Starlight	369 368	787 167	1 007 489	1 312 434	1 497 766
Autumn Royal	1 718 446	3 021 918	2 385 630	2 668 194	1 486 378
IFG 68-175 (Sweet Celebration®)	53 867	170 094	522 363	1 200 990	1 147 354
Sheegene 20 (Allison™)	80 229	186 698	404 855	875 376	1 148 749
Sugrasixteen (Sable Seedless®)	740 841	831 788	928 622	1 191 078	1 194 103
Regal Seedless	1 661 152	1 620 184	1 473 833	1 173 045	972 737
Grapaes (Early Sweet®)	782 563	1 196 241	1 523 530	2 406 667	1 050 525
Ralli Seedless	629 625	803 536	811 595	933 351	903 018
Sugrathirtyfour (Adora Seedless®)	5 534	19 666	87 746	390 814	697 910
Dan-Ben-Hannah	1 078 567	1 063 558	869 959	756 332	551 484
Other	9 320 179	8 593 601	7 628 960	8 260 304	7 162 592
GRAND TOTAL	50 311 308	58 544 992	56 659 880	65 448 438	59 132 945

Source: Lombardt, 2018

Table 7: Percentage change in Prime and Flame seedless over 5 years

	2014/2015 % change	2015/2016 % change	2016/2017 % change	2017/2018 % change
Prime Seedless	24%	4%	1%	-15%
Flame Seedless	29%	-2%	-18%	-20%

2.18 Conclusion

Despite the competitive nature of the international fruit industry, South African table grapes remain highly sought after. As long as exporters and stakeholders in the industry follow the basic rules of supplying consistent quality, led by the demands of each market segment, managing the cost chain, building solid relationships and maintaining market access, the long-term outlook for the future of the table grape industry is positive. Although a large number of role-players influence the effectiveness and efficiency of fresh produce cold chains, emphasis was placed specifically on the current flow of goods from farms that Company Y manages, and on the rules set out by the PPECB. Finally, best practices performing well in South Africa in other countries were discussed.

Although emphasis is placed on the importance of high RH percentages, little research has been done on the actual implementation of humidifiers in pack houses in South Africa, which makes this study valuable.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

Chapter 3 describes the methodology followed to gather data and the design of this research. It begins by introducing the choice of research methods that can be used and thereafter details the specific research method conducted for this study. It goes further, explaining the planning process for data collected in this research, the data tools used to analyse the data and the interpretation of the data. The final section provides a short summary to conclude this chapter.

3.2 Research Design

As previously stated, the discussion around the quality issues, such as brown stems, were at the genesis of this research. With hearing that the implementation of humidifiers had positive effects in decreasing the number of quality issues for Company X, Company Y implemented humidifiers into one of their pack houses to test this for themselves. As there is uncertainty on this particular subject matter, an explorative research design approach was taken.

An exploratory research design is a design methodology used to seek new insights by finding out "what is happening", to ask questions and to assess phenomena in a new light (Robson, 2002:79). Robson (2002:80) continues to say that this type of research design is particularly useful if the precise nature of the problem is unknown and the problem needs to be understood.

3.3 Research Strategy

There are seven main research strategies that can be employed in research. Only a case study research strategy is explained further, as this is the research strategy that this study employs.

1. Experiment
2. Survey
3. Case study
4. Action Research
5. Grounded Theory
6. Ethnography
7. Archival Research

3.3.1 Case study research strategy

According to Robson (2002:88), a case study is a research strategy and an empirical investigation that examines a phenomenon within a real-life context. Robson (2002:88) goes on further to say that case studies are based on extensive investigation of an occurrence, group or single individual to search the causes of underlying principles. It is a descriptive and exploratory investigation of the occurrence, group or individual. This type of research strategy investigates one case study or multiple case studies. It can include quantitative evidence, depends on several sources of evidence and gains from prior theoretical postulation. Case studies analyse a number of variables (systems), including, people, groups, policies, events, institutions and decisions that are studied holistically through one or several methods. In this study, data from several table grape farms was drawn and collected by Company Y. The already collected data was sent to the researcher for further investigation. The research strategy in this study is therefore a case study.

3.4 Methodology

There are two main data collection techniques and/or data analysis procedures. These are namely quantitative and qualitative. One of the main distinguishable differences between quantitative and qualitative data is that <u>quantitative</u> data is commonly used as a synonym for any data collection technique or data analysis procedure that uses or generates <u>numerical data</u>. While <u>qualitative</u> data on the other hand, is used generally as a synonym for any data collection technique or data analysis procedure that uses or generates <u>non-numerical data</u> (words). Choosing to use a single data collection technique (e.g. only interviews) and corresponding analysis procedure is called mono method. A multiple methods research choice can be split into two parts: 1) Multi-method and 2) mixed-methods. When using a multi-method research choice, the researcher can choose a number of quantitative <u>or</u> qualitative data techniques and procedures. On the other hand, when using a mixed methods approach, the researcher can use both qualitative <u>and</u> quantitative techniques and procedures. This breakdown can be seen more clearly in Figure 15.

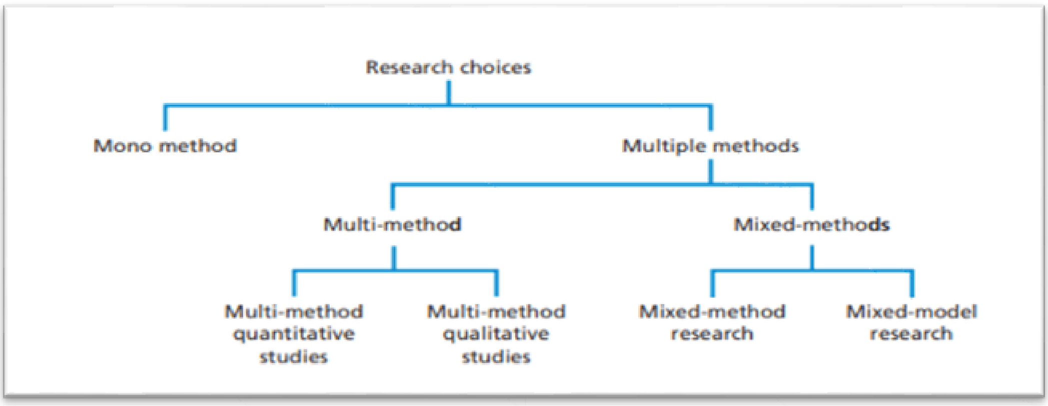

Figure 15: Research choices

Source: Saunders *et al.* 2003:155

Qualitative and quantitative data can be further broken down into nominal, ordinal, interval and ratio variables. The main variables related to this study are ambient temperature, relative humidity, quality control (QC) message and farm location. All data is broken down further in the next chapter.

Qualitative
- N- Nominal
- O- Ordinal

Quantitative
- I- Interval
- R- Ratio

3.4.1 Mixed Methods Research Methodology

In this research study, a mixed methods research approach was used, i.e. both qualitative and quantitative data was collected. Qualitative data was collected through reviewing literature and conducting interviews with the Logistics Manager from Company Y and a combination of both quantitative and qualitative data was collected using tools such as a thermometer to measure temperature (°C) and a hygrometer to measure humidity (%). The data used in this research included both primary and secondary data. The secondary data was collected through the literature review and by means of temperature and humidity data collected from farms managed by Company Y. The primary data was collected through interviews with the Logistics Manager at Company Y.

In this research, the data that was collected was analysed and represented through visual aids such as graphs and tables and investigated further by conducting hypothesis tests. The independent variable was ambient temperature and the dependent variable was relative humidity. However, both ambient temperature and relative humidity become dependent variables when the inferential statistics are conducted. Temperature and humidity are both measured before and after the manipulation of the dependent variable (the implementation of the humidifiers) for both the experimental and control groups. In this study, a case study was done based on temperature and humidity data that Company Y provided.

There were seven pack houses where temperature and humidity data were collected from. Temperature and humidity data were recorded every fifteen minutes, daily from November 2015 to February 2018. This data was automatically generated from the RH and temperature tools used to monitor these variables and transmitted to Company Y's database, so that it could be downloaded and analysed. The data was analysed through numerical comparisons and statistical inferences. The data collected was collected according to the following groups:

Experimental Group= Farm 1 pack house before and after implementing the humidifiers.

Control Group= six pack houses without humidifiers in the pack house (Farm 2 to Farm 7).

3.5 Statistics

Statistics is the science of collecting, analysing and interpreting data; it converts data into information. Data that is collected is called a sample and this sample is drawn from a population. Statistics can be broken into two categories, namely descriptive statistics and inferential statistics (Saunders *et al.* 2003:156). Various statistical terms and data such as the mean, standard deviation, coefficient, standard error and p-value assist in providing more quantitative data. With Quantitative data, results found have more basis to make valid conclusions in a study. Linking the fields of Statistics and Logistics Management allows logisticians to not only identify the gaps within their fields/departments/work environments, but highlights specific areas where these gaps occur.

3.5.1 Descriptive Statistics

Descriptive statistics is collecting, organising and summarising data using tables and graphs (Jaggia & Kelly, 2020:5). The data is summarised using bar graphs, histograms, line graphs, pie charts etc. The shape of the graphs can be used to describe the skewness of the graphs, which shows how the data is distributed. If data is distributed equally (normally), the graph will be symmetrical. If the data has more data distributed to the right or to the left of the graph, this shows the data is either skewed to the right or to the left. There are various measures of Central Tendency; namely the mean, median and mode. The mean is the average of the data, the median is the middle number of the data set and the mode is the number that occurs most frequently in the data set. Furthermore, there are various measures of variability; namely the range, variance and standard deviation. These descriptive techniques are used to describe and summarise the data that has been collected (Saunders *et al*. 2003:156). When conducting the descriptive statistics analysis in this study, the main variables analysed are temperature, humidity, farm location, quality messages (problems), grape varieties and time.

3.5.2 Statistical Inferential Analysis

Inferential statistics uses sample data to make an inference or to draw a conclusion of the population. A sample is a subset of the population (Jaggia & Kelly, 2020:5). The values that are drawn from the sample of data that is collected from the population, are called observations. Probability can then be used to determine how confident the researcher can be that the conclusions that are made are correct. Confidence intervals and margins of error are used in inferential statistics (Saunders *et al.* 2003:157). When conducting the inferential statistics in this study, the independent variable is the seven pack houses and the dependent variables are relative humidity, ambient temperature and quality.

3.5.3 Confidence level and Significance level

In statistics, the data being analyzed is usually a sample of the whole population of data. A sample is usually taken, because if a large amount of effort or other resources is needed to gather data and conduct the research, a smaller sample is taken to reduce the resources needed. The sample data collected should represent the population that the data was collected from. Therefore, a certain probability is determined to say that whether the sample evidence shows certain results, what is the probability that the sample data lies between a certain range (spread) of the population. In this study, a confidence level of 95% is used to determine the probability that the sample data lies within a certain range of the population mean. The margin of error is thus 5% (0.05). 0.05 is the significance level and represents the probability of a Type 1 error. The p-value is discussed in section 3.5.5. If the p-value is less than this significance level of 0.05, it shows that there is a probability greater than 95% that the sample represents the population. The room for error is smaller than 5%.

3.5.4 Hypothesis Testing

Although there have been a few experts that investigated the importance of high humidity levels of fresh grapes, there is inadequate information on the quality impact that RH and consequently temperature, have on fresh grapes, postharvest. By investigating, through thorough detailed analysis of data and literature, added knowledge in packing and distributing fresh fruit such as table grapes can be revealed.

To thoroughly analyze the results of the data that were collected, statistical hypothesis tests were done. Statistical hypothesis tests were used, because these tests will be able to ascertain whether there is sufficient evidence, in the sample of data collected, to conclude that a particular result is valid for the entire population.

Hypothesis Testing is used to deduce the result of a hypothesis performed on a sample of data from a larger population. When a hypothesis test is constructed, the null hypothesis ($\mathbf{H_0}$) and alternative hypothesis ($\mathbf{H_A}$) are defined:

$\mathbf{H_0}$: is the hypothesis the analyst believes to be true

$\mathbf{H_A}$: is the hypothesis the analyst believes to be untrue, making it effectively the opposite of a null hypothesis.

A hypothesis test is conducted to determine whether or not evidence from the sample, contradicts the alternative hypothesis (Jaggia & Kelly,2020: 294). If sample evidence conflicts with the null hypothesis, the null hypothesis is rejected. In contrariety, if the sample evidence does not contradict the null hypothesis, then the null hypothesis is not rejected. Jaggia & Kelly (2020) state that it is not correct to decide to “accept the null hypothesis”. Although the sample evidence may not be consistent with the null hypothesis, the evidence does not necessarily prove that the null hypothesis is true (Jaggia & Kelly, 2020: 294).

The aim of this study is to determine whether the implementation of the humidifier system has a positive effect on RH and ambient temperature and, therefore, reduces the quality issues of table grapes distributed. Three hypothesis tests needed to be conducted to provide evidence that either support the alternative hypothesis or reject the null hypotheses determined in this study.

Given that the average temperature and average relative humidity of several pack houses are being examined, the parameter of interest is the population mean. As Farm 1 has the humidifier system installed and the other six pack houses do not have the humidification system installed, the study needs to determine if the population mean of Farm 1 differs from the mean of the other pack houses.

Several research questions were identified in section 1.7. They were:

1. Does the implementation of humidifiers increase relative humidity at table grape pack houses in the Northern Cape?
2. Does the implementation of humidifiers decrease ambient temperature at table grape pack houses in the Northern Cape?
3. Does the implementation of humidifiers show a relationship between implementing the humidifiers and the quality of table grapes harvested in the Northern Cape?
4. Can humidifiers be implemented as a standalone source of improvement for the quality of table grapes harvested in the Northern Cape?

To answer the first two research questions, two hypotheses tests were conducted. Relative humidity and temperature were identified as the dependent variables and the pack houses were identified as the independent variables.

Hypothesis 1:

H_0: There is no difference in the mean values of relative humidity percentages when the humidifier system is installed versus the other pack houses where it is not installed.

H_A: There is a difference in the mean values of relative humidity percentages when the humidifier system is installed versus the other pack houses where it is not installed.

Hypothesis 2:

H_0: There is no difference in the mean values of ambient temperatures when the humidifier system is installed versus the other pack houses where it is not installed.

H_A: There is a difference in the mean values of ambient temperatures when the humidifier system is installed versus the other pack houses where it is not installed.

To answer the third research question, quality problems were identified as the dependent variable and the pack houses were identified as the independent variables.

<u>Hypothesis 3:</u>

H_0: The number of quality problems is the same at the farm where the humidifier system is installed and the other pack houses where it is not installed.

H_A: The number of quality problems is not the same at the farm where the humidifier system is installed and the other pack houses where it is not installed.

3.5.5 F- Statistic and P-Value

In this study, inferential data analysis will produce a test statistic, a p-value, that will enable this study to provide inferable conclusions. A p-value is very important in hypothesis testing as it is a probability that represents the possibility of capturing a sample mean that is as intense in both tails of the distribution (p-value, 2019). When the p-value is less than or equal to the significance level, it would show a significant difference in the mean of the two variables. However, if the p-value is greater than 0.05, it would show that there is no significant difference in the mean of the two variables. In this instance, it may show that there is no significant difference between the RH and temperature results that are produced at the farm with the humidification system installed and those without the system installed. If the significance level is **less than 0.05**, the null hypothesis will be rejected and will show a **significant relationship** between the dependent and independent variable. If the significance level is **greater than 0.05**, the alternative hypothesis is accepted, showing that the relationship between the dependent and independent variable is **not statistically significant.**

Therefore, in order to reject the null hypotheses of this experiment depends on the p-value (p-value, 2019). Through this hypothesis testing and the p- value, the various claims concerning the implementation of humidifiers in the pack house of table grapes can be made valid and generalized to a population of fresh table grapes.

In this study, the results produce two test statistics (F-value and t-value) that enables the study to provide inferable conclusions. The F-statistic, t-statistic and p-value are the values that are produced when an ANOVA is run. These values determine the significance of the test results. The greater the t-value, the more evidence is retained that the results derived are significantly different from the average. A smaller t-value provides evidence that the results derived are not significantly different from the average. Like the t-statistic, the F-statistic is used when deciding if the variance between two population means are significantly different. In the F-test results, both an **F-value and an F-statistic** are given. The value calculated from the data is called the F-value. Generally, if the calculated F-value in a test is larger than the F-statistic, the null hypothesis is rejected. However, the F-statistic is only one measure of significance in a F-Test. The p-value should also be considered. The F-statistic must be used in combination with the p- value when deciding whether the overall results are significant (Saunders et al. 2003:160).

3.5.6 Analysis of Variance (ANOVA)

All analysis examines some kind of variable(s). A variable can be measured, manipulated and controlled. There are two types of variables, namely an independent variable and a dependent variable. In this study, relative humidity, temperature and quality messages are a few of the main variables that are analysed in order to make deductions.

In this study, the objective was to determine if differences exist between the pack house with the humidifier system installed against the pack houses without the humidifier system installed. One way to make this determination is to compare the means generated from the data collected. An analysis of variance (ANOVA) test can assist in determining if differences exist between the means of the various pack houses investigated. The ANOVA test is based on the *F distribution* (Jaggia & Kelly, 2020: 349).

An ANOVA tests the null hypothesis (H_o), which assumes all group means are equal against an alternative hypothesis (H_A) where at least one group's mean is different. If the P-value is less than the significance level (0.05), the null hypothesis is rejected.

The ANOVA can only be used to determine whether a difference exists, but it cannot identify where the difference lies (Keller, 2011: 221). For example, in this investigation, the ANOVA may reveal that there are significant differences in the means of temperature and humidity amongst the various pack houses, but other descriptive analysis may reveal where the differences lie.

There are two ANOVA tests that can be conducted to compare population means – the first is a one-way ANOVA test and the second is a two-way ANOVA test. In this study, a one-way ANOVA is conducted, as this ANOVA test compares population means that are based on one categorical variable or factor (Jaggia & Kelly, 2020: 350). This study's categorical variable for the ANOVA test is the seven pack houses (Farm 1 to Farm 7). In an ANOVA test, the critical value is the F-statistic. However, as stated above, if the P-value is less than the significance level (0.05), the null hypothesis is rejected.

3.5.7 Analysis of Covariance (ANCOVA)

Like the ANOVA, the analysis of covariance measures and compares the means of categorical variables against a continuous dependent variable (Dunn & Clark, 1987: 325). However, the major difference between an ANOVA and an ANCOVA is that an analysis of covariance combines the ANOVA with a regression analysis and analyses several regressions due to different categories. It conducts a regression of the independent variable (i.e. the covariate) on the dependent variable and measures the means of the dependent variable across multiple levels of the independent variable (Dunn & Clark, 1987: 325). The ANCOVA determines the effects of the relationship between the categorical variable and the continuous dependent variable (Dunn & Clark, 1987: 326). In this study, the variables used in an ANCOVA test are RH as the response variable and temperature as the covariate (independent variable), the different categories being Humidifier =No (N) and Humidifier =Yes (Y). The ANCOVA also produces a p-value. If the P-value is less than the significance level (0.05), the null hypothesis is rejected.

3.5.8 Bonferroni Test

The <u>ANOVA</u> test evaluates whether the probability of making a Type 1 error is less than or equal to significance level of 0.05 for the <u>whole set</u> of tests. The Bonferroni test, on the other hand, evaluates the probability for only one test at a time. Simply, the ANOVA reveals that there is a significant difference between the means of the independent and dependent variables, but the Bonferroni test provides more detail to show where this significant difference lies. The Bonferroni is similar to the ANCOVA where it conducts an analysis of the independent variable on the dependent variable and measures the means of the dependent variable across multiple levels of the independent variable (Saunders et al. 2003:201).

For example:

Farm 1 tested against -Farm 2

Farm 3

Farm 4

Farm 5

Farm 6

Farm 7

Farm 2 tested against- Farm 1

Farm 3

Farm 4

Farm 5

Farm 6

Farm 7

…and so on. The Bonferonni test procedure is a sequential approach whose goal is to "increase the power of the statistical tests while keeping under control the familywise Type I error" (Aickin & Gensler, 1996: 727).

Determining the test statistic in this sort of experiment takes a substantial amount of time. As a result, computer programs such as Statistica®, Microsoft Excel were used to produce the statistics needed.

All statistical measures that are used in this study are summarised in section 3.5.10 to follow. Statistical measures and their definitions are tabulated to simplify the measures for the researcher and the reader.

3.5.9 Pearson's chi-squared test

Pearson's chi-squared test is used to determine whether there is a statistically significant difference (i.e., a difference which is not just due to chance variations) observed between sets of categorical data. The purpose of the test is to evaluate how likely the observations that are made would be, assuming the null hypothesis is true. If the null hypothesis is true, the sampling distribution approximates a chi-squared distribution more and more closely as the sample size gets larger. The important difference in a chi-squared test is that because the null hypothesis is assumed to be true, <u>in order to show that there's a significant difference in the means of the data, the p-value for the alternative hypothesis needs to be less than the significance level (0.05).</u> The p-value for the null hypothesis would thus be greater than 0.05 (Dunn & Clark, 1987). This test will be used when testing hypothesis 3.

3.5.10 Summary of statistical measures

A summary of statistical measures that is used in this study is given in the following table. Table 8 provides the name of the statistical measure and a short definition that summarizes the measures that will be used to analyse the data collected in this study. It's important to understand these measures as they explain the reasoning for certain conclusions made from the data collected.

Table 8: Showing summary of statistical measures and its definition

STATISTICAL MEASURE	DEFINITION
SSE (sum squared error):	The SSE statistic measures the total deviation of the resulting values from the fit to the response values. This measure is also called the summed square of residuals and is usually labelled as SSE. A value that is closer to 0 indicates that the model has a smaller random error component, and that the fit will be more useful to make a prediction about the general data.
MSE (mean squared error):	The mean squared error can tell how close a regression line is to a set of points. This is done by taking the distances from the points to the regression line (these distances are the "errors") and squaring them. The smaller the means squared error, the closer one is to finding the line of best fit (regression line). Depending on the data, it may be impossible to get a very small value for the mean squared error. A MSE value closer to 0 indicates a fit that is more useful to make a prediction about the general data.
R-Squared:	The R-squared statistic measures how successful the fit is in explaining the variation of the data. In other words, R-square is the square of the correlation between the resulting values and the predicted values. This value can take on any value between 0 and 1, with a value closer to 1 indicating that a greater proportion of variance is accounted for by the model. For example, an R-square value of 0.7753 means that the fit explains 77.53% of the total variation in the data about the average.
Standard error:	The standard error (SE) is similar to standard deviation. Both these measures are measures of spread. The higher the number, the more spread out the data is. There is one important difference between standard deviation and standard error. While the standard error uses statistics (sample data), the standard deviation makes use of parameters (population data). The SE tells one how far the sample statistic (for example, the sample mean) deviates from the actual population mean. The larger the sample size, the smaller the SE. Simply put, the larger the sample size, the closer the sample mean is to the actual population mean.
Standard Deviation	The samples variance (s2) and sample standard deviation (s) measures the

	dispersion of the data that's collected (Jaggia & Kelly, 2020:97). A low standard deviation indicates that the values in the data tend to be close to the mean of the set, while a high standard deviation indicates that the values are spread out over a wider range.
P-value (significance):	The p-value tells what the odds are that the results could have happened by chance. If the p-value is less than the significance level, in this study (0.05), the results are not by chance, but provide significant evidence about the relationship between variables. If the p-value is greater than the significance level, it is more likely that there is a weak relationship between the variables analysed. The p-value, combined with the test statistic, can only reject the null hypothesis.
t-statistic	The t-statistic is used in a t-test when a decision needs to be made whether the null hypothesis should be rejected. The t-statistic does not really add value on its own, but when used in conjunction with the p-value, a solid conclusion can be made. The greater the t-value, the more evidence is retained that the results derived are significantly different from the average. A smaller t-value provides evidence that the results derived are not significantly different from the average.
F- statistic	Like the t-statistic, the F-statistic is used when deciding if the variance between two population means are significantly different. In the F-test results, both an **F-value and an F-statistic** are given. The value calculated from the data is called the F-value. Generally, if the calculated F-value in a test is larger than the F-statistic, the null hypothesis is rejected. However, the F-statistic is only one measure of significance in a F-Test. The p-value should also be considered. The F-statistic must be used in combination with the p- value when deciding whether the overall results are significant. Why? If the test produces a significant result, it does not mean that all the variables are significant. The statistic is only comparing the joint effect of all the variables together. This value is used when conducting an ANOVA test.
ANOVA	Analysis of Variance (ANOVA) is a statistical method used to test differences between

	two or more means. Inferences about means are made by analysing any variance. An ANOVA test is used to test general rather than specific differences among means. There are 2 types of ANOVA tests: 1) A one-way ANOVA tests the mean difference between two variables. 2) A two-way ANOVA tests the mean difference between more than two variables. ANOVA tests the non-specific null hypothesis that all population means are equal.
Mean/Average	The mean or average is calculated to obtain the central tendency of a set of data. The mean is calculated by summing all data points of a sample or population and dividing it by the number of total number of data points in that sample or population set. The use of a mean or average value makes all the different values into a uniform value. It tries to remove any variances or outliers in the data.
Median	The median is the exact middle value of the data set. If the data set is an even number of values, there will be two “middle” numbers. These two numbers need to be summed and divided by two to derive the median.
Variance	The variance shows how far the sample data is spread out from its average value.

Source: Saunders *et al.* 2003:160

3.6 Ethical Considerations

3.6.1 Permission and Confidentiality

Company Y provided a signed, written document that permitted this study to be conducted by the researcher. In addition, Company Y supplied the data that was collected, by the company, to the researcher to analyse and provide deductions. The signed document grants the researcher permission to examine the data without divulging any confidential information.

The researcher agreed to keep all information, pertaining to Company Y, confidential by making use of pseudonyms. This was done to ensure the protection of all participants from any form of abuse, harm or harassment. Throughout this document the pseudonyms used are the following:

Company X, Company Y, Farm 1, Farm 2, Farm 3, Farm 4, Farm 5, Farm 6 and Farm 7.

3.6.2 Data Collection

Company Y played a vital role in terms of data collection. Data was collected at several pack houses, with one of these (Farm 1) having the humidifier system installed. During this time, the 2015 to 2018 table grape seasons, ambient temperature, relative humidity and various other important data was collected for the grapes that were harvested, packed and exported across the world. At these final destinations, data was also collected regarding the quality of grapes received. These grapes were graded according to the seriousness of the quality issues, its financial impact and departmental responsibility for the loss, if there was any.

3.6.3 Software

This study was conducted using various software programs to provide complete and accurate information. Firstly, the data that was collected by Company Y was extracted from various tools and exported to Microsoft Excel workbooks. The researcher made use of Microsoft Word to write up this report. In addition, Microsoft Excel was used to draw up data tables and Analysis of Variance (ANOVA) tables. The majority of the data analysis was done using Tableau®, which is a data visualisation program. This program allows its users to input big data, analyse and present it in a user-friendly way. Finally, the researcher also made use of a statistical program called Statistica® that provided statistical information such as p-value and f-value outputs.

3.7 Description of Variables

Two data sets were shared with the researcher. The first data set was consolidated data that was collected at each of the seven pack houses. These data sets showed the exact farm the data was collected at (Farm 1 to Farm 7), the ambient temperature and relative humidity values that were collected, the date and time of collection (at 15 minute intervals), the process stage that these values were gathered at, for example, at the precooler or packing line and furthermore a column that showed whether there were humidifiers installed at that particular time, farm or process stage (Y= yes, humidifiers installed and N= no, humidifiers not installed). This data set is referred to as <u>data set 1</u> for the remainder of the thesis. This data set is illustrated in Table 9 Moving from left to right, Table 9 tabulates each variable, providing a description, specifying if it is categorised as qualitative (QL) or quantitative (QN) data, further describing the data as being Nominal, Ordinal, Interval or Ratio (NOIR) and providing an example of each.

Table 9: Showing descriptive variables from data set 1 collected at pack houses

Variable	Description	QL or QN	Type of data (NOIR)	Example
FARM_LOC	Location of the pack houses where the grapes were harvested/packed/stored.	QL	Nominal	FARM 7
DATE	The date the data was collected.	QL/QN	Interval	17/11/2015
TIME	The time the data was collected (15-minute intervals).	QL/QN	Interval	10:15:47
TEMPERATURE	The temperature captured on the specific day and time (°C).	QN	Ratio	24.3
HUMIDITY	The humidity captured on the specific day and time (%).	QN	Ratio	43.7
HUMIDIFIER Y/N	Shows if the process stage has humidifiers installed at that farm location. Y=Yes, N=No	QL	Nominal	N
PROCESS STAGE	Process flow that the grapes go through from the time of harvest to the point of being packaged and stored, ready to be distributed.	QL	Ordinal	PACKLINE

As stated previously, two data sets were provided. The second data set gathered a wider variety of information such as pack location (Farm 1 to Farm 7), the market the grapes were packed for and shipped to, quality control (QC) messages, port of loading (POL), port of destination (POD), container volumes shipped etc. This data set is referred to as data set 2 for the remainder of the thesis and is more detailed in Table 10. The data at the pack house (data set 1) and at the port of destination (data set 2) was linked through the pack house details, i.e. the farm location in data set 1 and the pack location in data set 2. Table 10, like Table 9, tabulates each variable, providing a description, specifying whether it is categorised as qualitative (QL) or quantitative (QN) data, and further describing the data as being Nominal, Ordinal, Interval or Ratio (NOIR) and providing an example of each. Data was collected daily, at fifteen-minute intervals from 17 November 2015 to 23 January 2018.

Table 10: Showing descriptive variables for data set 2

Variable	Description	QL or QN	Type of Data (NOIR)	Example 1	Example 2
season	Year of harvest/dispatch	QL	N	2018	2018
pack_location	Location of the pack houses where the grapes were harvested/packed/stored.	QL	N	FARM 6	FARM 6
farm	Numerical ID attached to the farm/pack location.	QL	N	A8007	A8007
intake_targ_mkt	Intake target market. Market for which the grapes were packed for.	QL	N	FE	TE
ctn_qty	Actual Carton Quantity	QN	R	180	96
in_date	intake date	QL/QN	I	18/01/2018	17/01/2018
in_locn	intake location	QL	N	FARM 5	FARM 5
pack_date	Date grapes were packed	QL/QN	I	18/01/2018	17/01/2018
pol	Port of loading	QL	N	ZACPT	ZACPT
pod	Port of destination	QL	N	HKHKG	NLRTM
rec_country	Receiving country	QL	N	HK	NL
export_week	Week # grapes were exported.	QL/QN	I	201804	201804
stuff_date	Date grapes were packed into the containers.	QL/QN	I	21/01/2018	18/01/2018
variety	Type of grape varietals.	QL	N	AUTUMN CRISP	KRISSY
var_grp	Type of grape varietals in specific groups.	QL	N	WS	RS
grade	Quality defects graded to determine the type of claim.	QL	O	0	1
claim_type	Seriousness of the claim.	QL	O	0	NO CLAIM

std_ctn_qty	Standard 4.5kgs equivalent cartons.	QN	R	180	106.6666666
size_count	Depends on the standard container quantity.	QL	O	XL	L
qc_message	Quality control messages to determine grade of grapes and claim.	QL	N	BLEMISHES	GOOD CONDITION
load_locn	Location where grapes were loaded before being transported to the POL.	QL	N	CFC	FARM 3

At Farm 1's pack house, the humidifiers are installed only at the pre-cooling chamber. This installation and use of the humidifier system commenced on 16 December 2015. Data prior to this date at Farm 1's pack house was also collected and analysed.

From data set 2, quality control (QC) messages were recorded once shipments were received and checked at the port of destination. When the grapes are checked, they are graded according to the quality of the grapes. If the grapes are graded "0", quality issues were picked up and this will have a financial impact for Company Y. If the grapes are graded "1", the grapes are found to be in a good, acceptable condition. If the grapes are graded "3", the grapes were found to have quality issues, but they are acceptable with no financial impact. This is illustrated in Table 11.

Table 11: Showing grade of table grapes

GRADE	Description
0	Quality issues – financial impact
1	Good quality
3	Quality issues – no financial impact

Furthermore, grade "0" is broken down into two claim types. Claim type "1" is a claim that bears a financial impact, however, this financial impact could fall on any stakeholder responsible within the supply chain. Claim type "5" clearly defines that this is a logistical claim and this financial impact will fall onto the logistics team. This is displayed in Table 12.

Table 12: Showing Claim Type due to quality issues

CLAIM TYPE	Description
0	Claim with financial impact

5	Logistical claim with financial impact

Furthermore, in this study, the following variables are used interchangeably and are used in the same manner as each other, without any important differences. For example, when "ambient temperature" is stated, the text "temperature" could be used as they both mean the same in this study.

1. Ambient temperature and temperature
2. Relative Humidity (RH) and humidity
3. Pack location and farm

3.8 Conclusion

This chapter concludes by highlighting main takeaways from the design and methods that are used in this study. This study is based on a case study research methodology, highlighting one main hypothesis that is tested. A number of variables are analysed using various tools in order to provide enough statistical evidence to reject or fail to reject the null hypothesis and essentially answer the research questions established in this study.

CHAPTER 4: DATA ANALYSIS

4.1 Introduction

Both qualitative and quantitative data played an important role in this study. Qualitative data was gathered through researching literature in order to form the basis of analysing the results revealed in this research. Quantitative data was collected by Company Y and given to the researcher to analyse. In this chapter, the data that was collected by Company Y is illustrated in the form of graphs, tables and figures. Both descriptive and inferential statistics are used to provide explicit answers to the research questions in this study. The chapter opens with the broad framework of Company Y's main export destinations, and thereafter, drills down to activities within the pack houses being investigated. The chapter closes with a brief review of main data points revealed from the data collected.

4.2 Main export countries

In Figure 16 shows the top four countries that Company Y exports to on a world map. The map was developed using the total container quantities that were distributed by Company Y over the years 2015 to 2018. The countries that the highest quantities were supplied to, over this period were:

1. Great Britain (GB)
2. Belgium (DE)
3. Canada (CA)
4. Netherlands (NL)

The size of the circles on the graph shows summed volume that was distributed and relates to the receiving country. From Figure 16, it can be seen that Great Britain far exceeds the other three countries in terms of volume that Company Y exports to. Furthermore, the importance of this information is to show that three out of the four high volume countries are in Europe and the standard of quality of fresh produce imported into European markets are above any other country (PPECB, 2019).

Figure 16: Volumes of grapes exported to receiving countries over the period 2016 to 2018

4.3 Relationship between humidity and temperature

This section looks to identify the relationship between temperature and relative humidity. As Grierson & Wardowski (1978) described, that if the temperature is increased while keeping the moisture content constant, the RH decreases and when the temperature is decreased, while keeping the moisture content constant, the RH increases. This is seen as an inverse relationship.

4.3.1 Comparison of trend lines at farms with humidifier system (Y) and without humidifier system (N)

From Vaisala (2012), the control group is the independent variable (ambient temperature (°C) in this study) and the experimental group is the dependent variable (the relative humidity (%) in this study). The independent variable is plotted on the horizontal axis and the dependent variable is plotted on the vertical axis. As can be seen in Figure 17, when looking at the scatter plot of humidity (without a humidifier system) against temperature, the scatter plot shows that as temperature increases, relative humidity decreases. This is shown by the negatively sloping, black “trend line”, also known as the regression line. The trend of this line shows a steep decreasing relationship. The dots are gathered closely around the trend line. The relationship can be described as strong.

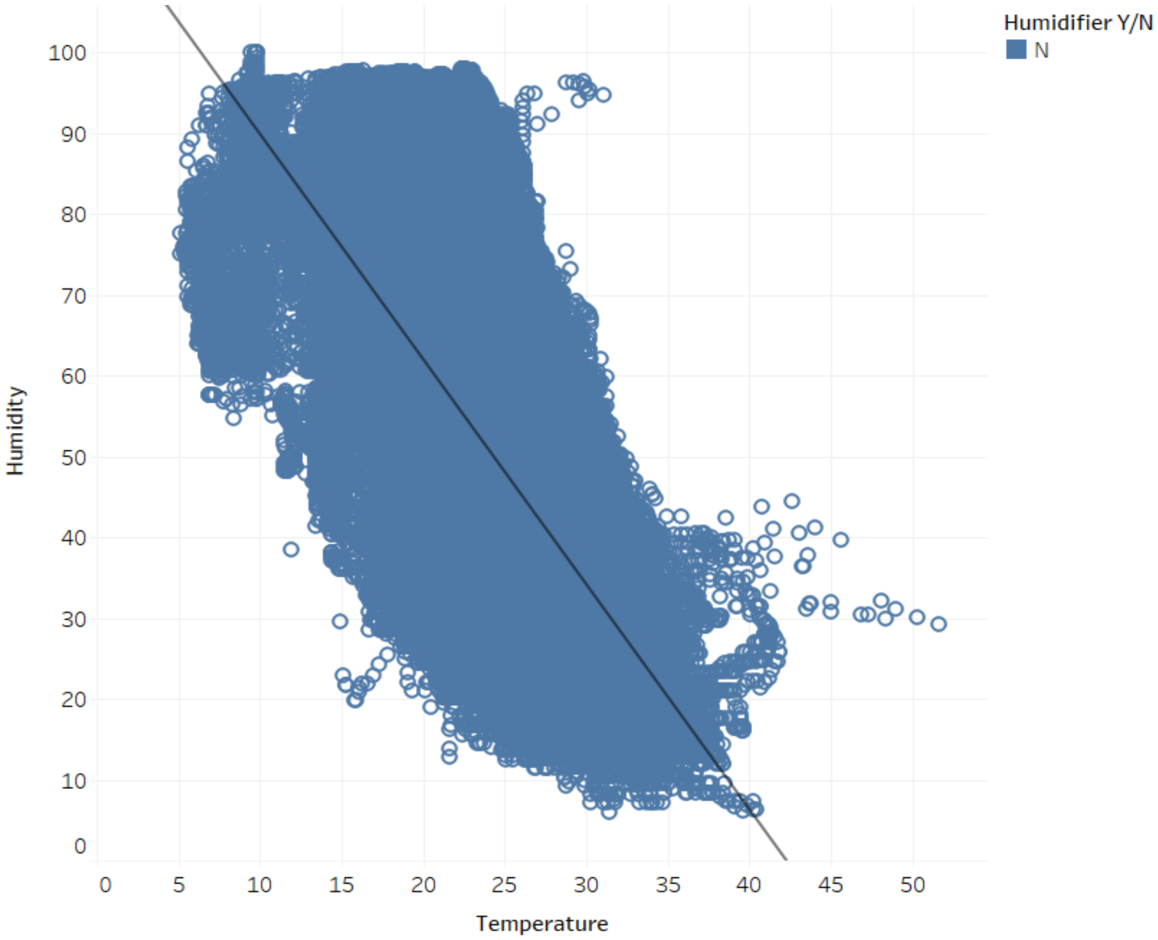

Figure 17: Ambient temperature versus relative humidity without humidifiers across all seasons

Figure 18 plots the temperature and RH of farms, with and without the humidification system installed, onto one graph. There are two variables, namely RH and temperature. These are measured under two conditions (the factor humidifier system) being present or not. It can be seen in the scatter plot graph (Figure 18) that when temperature and RH data of both groups (with and without the humidifier system) are plotted on the same graph. Both trend lines have a negative slope that can be interpreted as, increasing temperature, decreasing humidity. The orange trend line of the group of data with the humidification system installed is a steep downward facing line that is further out towards the right than the blue trend line that is more towards the left of the graph. The orange trend line when compared to the blue trend line shows that it takes higher temperatures to decrease the humidity to the same level as when there is no humidification system installed. This could be interpreted as if table grapes that were distributed from a pack house with a humidification system installed, were to experience higher temperatures at some point in the supply chain, the RH would not drop as quickly if they were distributed from a pack house without a humidification system installed. The stresses caused from the drop in RH would not happen as quickly for table grapes that were packed in a pack house with a humidifier system installed.

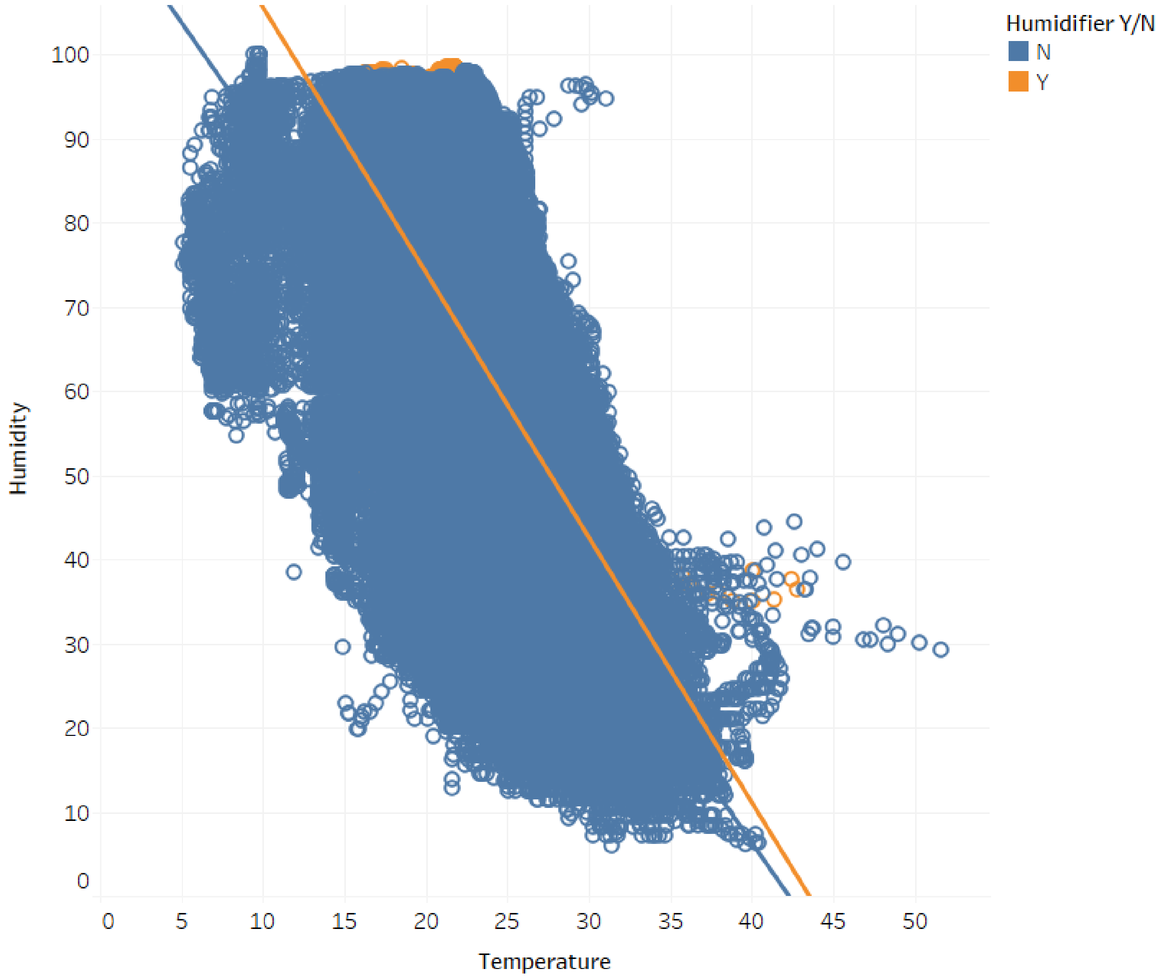

Figure 18: Scatter plot of temperature versus humidity of farms both with and without a humidifier system

4.4 Mean temperature and RH

4.4.1 Relationship between means

The daily average temperature and relative humidity, over the three grape seasons, is graphed in this section. In the line graph (Figure 19), the average temperature of the seven pack houses over the different seasons, years 2015 to 2018, is depicted. The graph shows that the lowest average temperature over the three seasons is experienced at Farm 1, which has the humidification system installed. Farm 1's average temperature is represented by the blue line, which seems to be experiencing less variation in average temperature than when compared to the other farms. This is shown by a more "flat line" than the other farms. Overall, the farms experienced an average ambient temperature of 23.17°C. To add further detail, Table 13 shows the minimum, average, maximum and median values of the ambient temperature experienced each pack house over the three seasons. By placing the values next to each other in a tabular form, this shows how each pack house compares to each other using these four descriptive statistics. A distinct difference is seen in the average ambient temperatures of the pack house with the humidifier system installed (Farm 1) and the other pack houses without the humidifier system installed. In Table 13, it can also be seen that across all three grape seasons, Farm 1 experienced the lowest temperatures. The difference in minimum and maximum ambient temperatures seem to be quite widely spread across all the farms. As the data measures the ambient temperatures across all the process stages, this could impact these values. At one process stage such as the "Sluiskamer" much lower temperatures would be experienced, because it is close to the forced cooling chamber, whereas the "pack line" and "precooler" may experience higher temperatures, because they are closer to temperatures outside the pack house. In 2016, 2017 and 2018, Farm 3 experienced the highest average ambient temperatures. They were 25.61°C, 23.17°C and 23.04°C, respectively.

At some point in the 2016 grape season, Farm 3 reaches an ambient temperature of 30°C. From literature, Haasbroek (2013) advised that best practice, is to maintain ambient temperatures between 18°C and 25°C within table grape pack houses. Although the ambient temperatures are seen to be unstable, the 7°C gap between 18°C and 25°C allows for some flexibility. However, it is very concerning to see in Table 13, that in 2018, Farm 1 and Farm 6 reached temperatures of over 50°C.

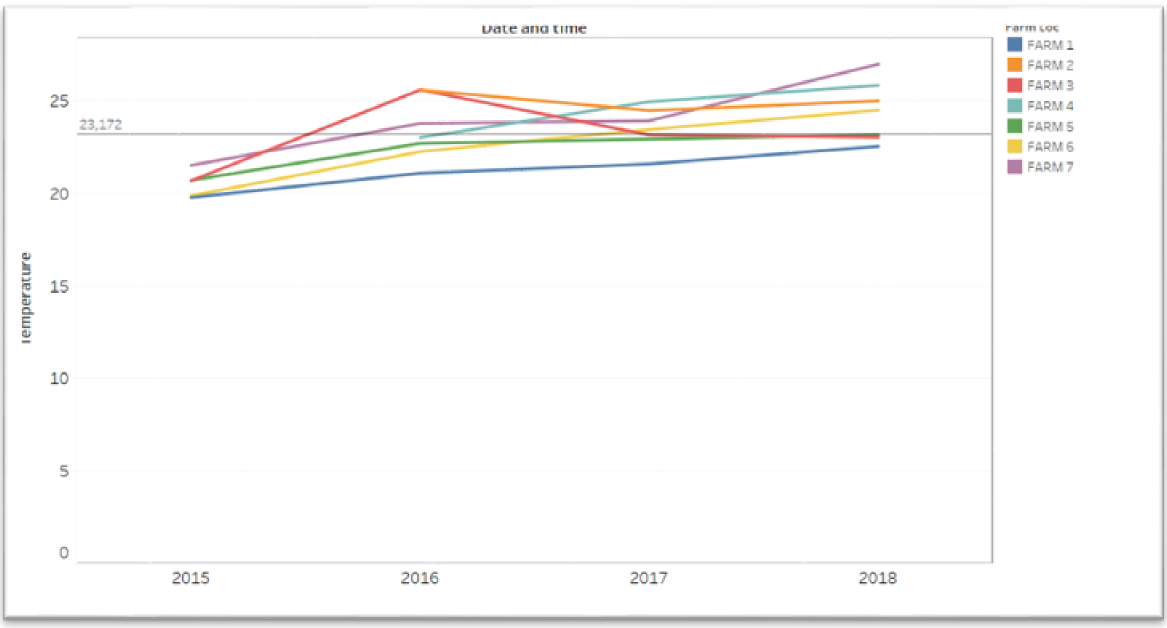

Figure 19: The trend of average temperature over all seven farms for period 2015-2018
Colour shows details about pack house (farms)

Table 13: Table depicting minimum, average, maximum and median measures for ambient temperature at the seven farms over the 3 seasons

	Date and time											
	2016				2017				2018			
Farm Loc	Minimum (T)	Average (T)	Maximum (T)	Median (T)	Minimum (T)	Average (T)	Maximum (T)	Median (T)	Minimum (T)	Average (T)	Maximum (T)	Median (T)
FARM 1	14,60	21,10	30,30	21,60	7,70	21,60	30,30	22,70	5,10	22,55	50,30	23,90
FARM 6	5,10	22,27	30,10	23,30	8,60	23,47	33,20	24,80	12,60	24,51	33,40	25,30
FARM 5	13,50	22,72	30,90	23,30	12,70	22,95	33,90	23,70	12,70	23,17	32,90	24,00
FARM 4	13,30	23,03	36,60	22,90	10,60	24,97	37,40	25,50	16,00	25,85	41,30	25,40
FARM 7	15,20	23,80	31,70	23,80	12,70	23,94	33,50	24,30	14,80	26,99	33,60	27,70
FARM 2	18,70	25,60	33,20	25,60	11,80	24,49	34,20	25,00	13,70	25,02	41,80	25,30
FARM 3	11,90	25,61	39,60	26,40	5,50	23,17	37,00	24,70	6,70	23,04	51,60	25,20

In the line graph (Figure 20), the average relative humidity of the seven pack houses over the three seasons (2015-2018) is depicted. The line graph shows that the highest relative humidity over the majority of the three seasons is experienced at Farm 1, which has the humidification system installed. Although, it can also be seen that Farm 1's RH increases from 2015 to 2016 and thereafter begins to decrease between 2016 and 2017 and further declines in 2018, but with smaller variation in the average RH (the gradient of the line is not as steep when compared to the time between 2016 and 2018). Farm 1's average relative humidity is represented by the blue line. The humidification system was implemented in December 2015, as mentioned in the methodology section. This could be the reason why Farm 1 experienced a hike in RH around that time, but it can also be seen that there is a drop in the RH between the 2017 and 2018 seasons. This drop in RH between the 2017 and 2018 seasons could be due to the increase in average temperature over the same period, as seen in Table 13. Looking at the various lines on the graph, all of the farms seem to be experiencing fluctuating relative humidity. Best practice from previous literature recommends that humidity be maintained between 90%-95% (Haasbroek, 2013). To show this recommended RH, reference bands are added in Figure 18. It is seen that none of the farms come close to the reference bands.

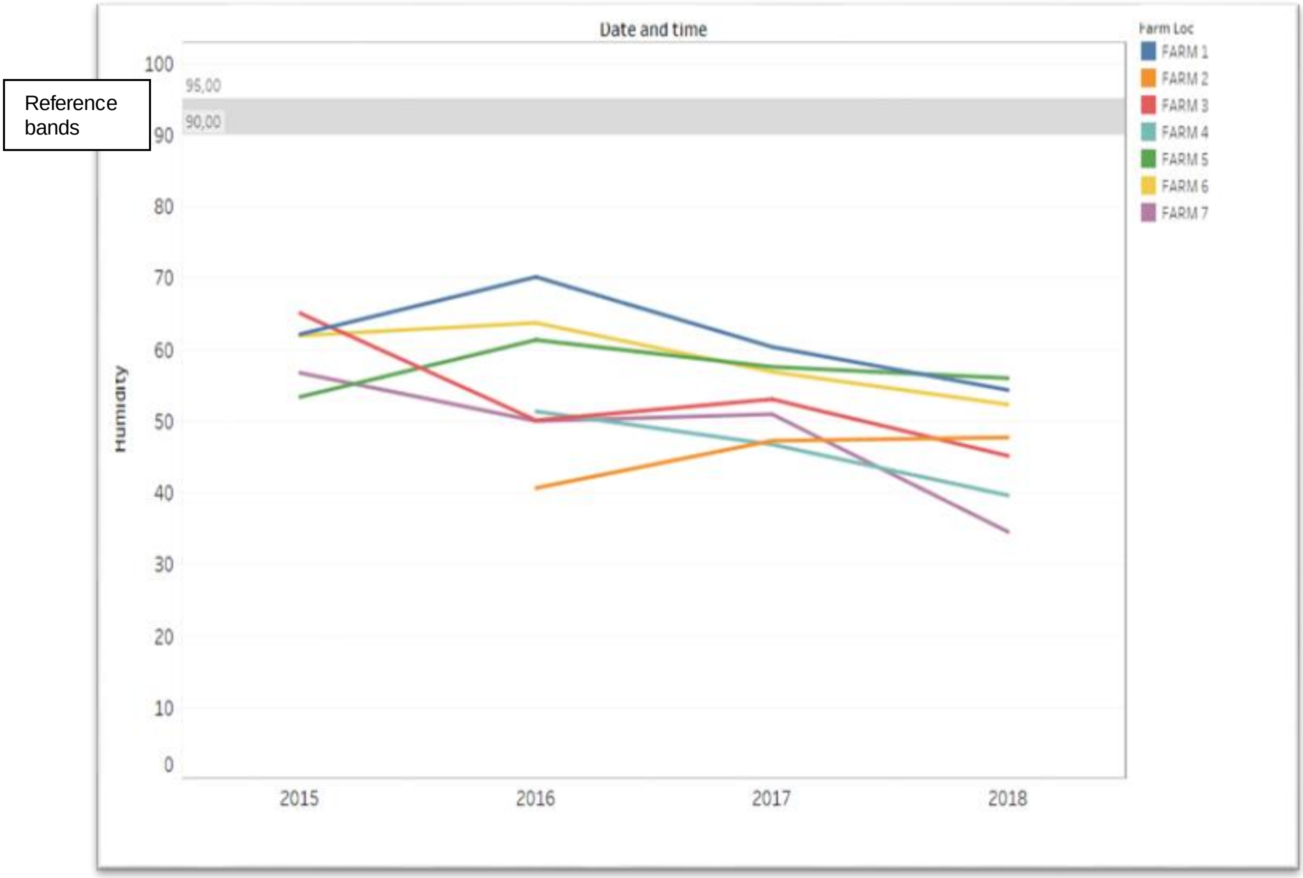

Figure 20: Line graph showing relative humidity over seven farms over the period 2016 to 2018

To add further detail, Table 14 shows the minimum, average, maximum and median values of the relative humidity experienced at all the pack houses over the three seasons. By placing the values next to each other in a tabular form, a distinct difference is seen in the average RH of Farm 1 with the humidifier system installed and the pack houses without the humidifier system installed. In Table 14, it can also be seen that across all three grape seasons, Farm 1 did not experience the highest RH. Farm 1 experienced the highest RH in the first two seasons and Farm 5 experienced the highest average RH in the last season. The difference in minimum and maximum relative humidity seems to be quite widely spread across all the farms. Again, this could be due to the data being measured across all the process stages. This could skew the data. In 2016, 2017 and 2018, Farm 4's RH dropped down to minimum single digit humidity percentages. These were 9.4%, 6.0% and 6.20%, respectively. This is worrying, because no matter which process stage the grapes are in, the RH should be maintained at high double-digit percentages. Overall, the average humidity is very low and often unstable, which could cause stresses on the fruit.

Table 14: Depicting the relative humidity of the seven farms over the period 2016 to 2018

	Date and time											
	2016				2017				2018			
Farm Loc	Minimum (H)	Average (H)	Maximum (H)	Median (H)	Minimum (H)	Average (H)	Maximum (H)	Median (H)	Minimum (H)	Average (H)	Maximum (H)	Median (H)
FARM 1	22,50	70,15	98,50	73,70	23,00	60,38	98,40	58,70	21,50	54,36	95,30	48,80
FARM 6	16,00	63,75	100,00	65,20	16,10	56,91	97,60	54,80	11,60	52,34	97,70	47,15
FARM 5	20,50	61,36	97,50	60,70	14,80	57,59	97,50	55,60	18,30	56,02	97,50	51,60
FARM 4	9,40	51,38	92,90	50,10	6,00	46,76	96,70	43,10	6,20	39,64	95,00	41,20
FARM 3	11,70	50,14	94,50	45,50	12,80	53,07	96,70	53,00	10,00	45,16	91,80	42,80
FARM 7	15,40	50,04	87,30	47,70	18,70	50,99	91,50	48,80	11,60	34,55	86,80	30,60
FARM 2	12,70	40,67	68,30	39,75	9,20	47,28	91,00	44,70	12,70	47,74	88,90	45,00

Below in figure 21 a comparative view of the average relative humidity and ambient temperature across all farms, with and without humidifiers, over the period 2015-2018 is given. This figure differs from figure 20 and 21 because figure 19 combines the average of all farms segregating them between with humidifier (Y) and without humidifier. The values in <u>blue</u> are the average temperatures and humidity <u>without</u> humidifiers. The values in <u>orange</u> are the average temperature and humidity <u>with humidifiers</u>. The first row shows that the values of average humidity with humidifiers (orange) are substantially higher compared to average humidity without humidifiers (blue). This trend is sustained from 2015 to 2018. The second row shows the values of average temperature with humidifiers (orange) being lower than when compared to average temperature without humidifiers (blue). This trend is sustained from 2015 to 2018. From literature, increased ambient temperatures decreases humidity percentages (Vaisala, 2012), which can be seen in the averages of the temperature and RH from farms without humidifiers and decreased ambient temperatures and increased RH of farms with the humidification system installed.

	Date & Time				Humidifier Y/N
	2015	2016	2017	2018	N
Avg. Humidity	59,34 81,81	55,35 82,53	52,65 67,47	46,88 59,25	Y
Avg. Temperature	20,56 16,87	23,64 18,93	23,52 22,15	24,22 22,86	

Figure 21: Average humidity and Average temperature broken down by Humidifier Y/N and by date

A boxplot displays the “five-number summary” (the minimum, the first quartile, second quartile, third quartile and the maximum value. This is a useful tool when comparing the information that is gathered from all the pack houses. It is also able to identify if there are any outliers or skewness in the data (Jaggia & Kelly, 2020:97).

The box and whisker plot in Figure 22 shows the spread of the ambient temperatures over the three seasons at different process stages within the pack houses. The data is also broken down at the precooler process stage, where the humidifier system is installed.

At the pack line, the lowest temperature recorded is 16°C and the highest is 33°C. Thus, the range is equal to 17°C. The median at this process stage is 24°C, which shows that half of the ambient temperatures fall below 24°C and half fall above 24°C. The range is smallest at this process stage, but also shows quite a few data points falling outside of the range.

At the precooler without the humidifier system (N), the lowest temperature recorded is 6°C and the highest is 38°C. Thus, the range is 32°C. The median at this process stage is 22°C, which shows that half of the ambient temperatures fall below 22°C and half fall above 22°C.

At the precooler with the humidifier system (Y), the lowest temperature recorded is 14°C and the highest is 37°C. Thus, the range is 23°C. The median at this process stage is 20°C, which shows that half of the ambient temperatures fall below 20°C and half fall above 20°C. Figure 22 shows that these temperatures are more controlled with a smaller range and ambient temperatures falling closer to the lower quartile of the box and whisker plot.

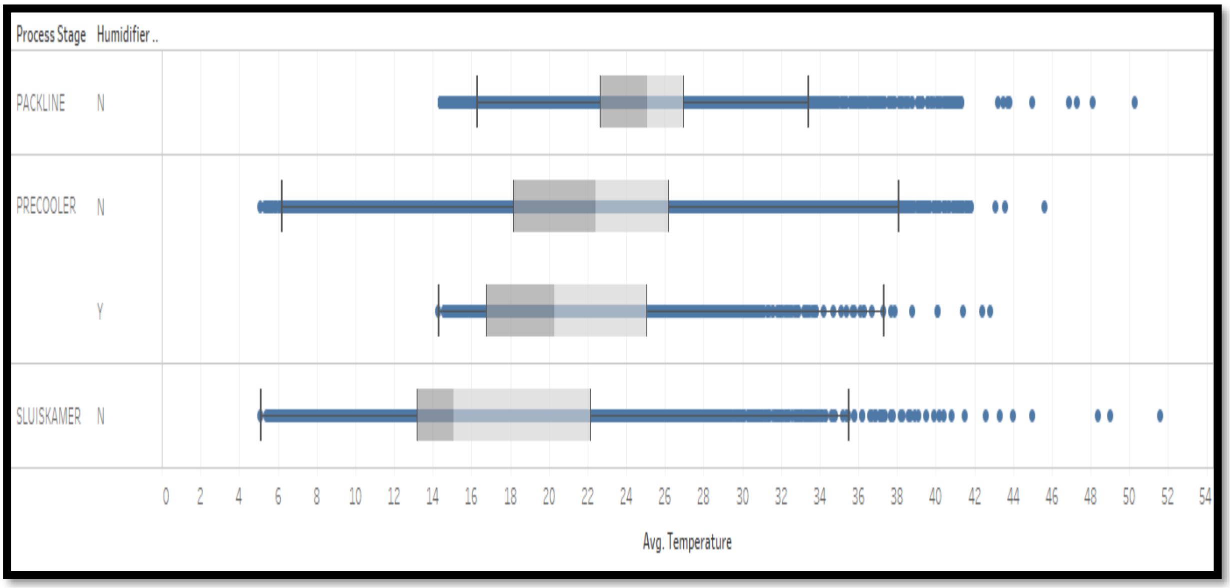

Figure 22: Box plot of average temperature for humidifier system Y/N broken down by process stage over 3 seasons

At the Sluiskamer (this is an intermediate holding area for the packed grapes before it moves to the forced cooling chamber), the lowest temperature recorded is 5°C and the highest is close to 36°C. Thus, the range is 31°C. The median at this process stage is 15°C, which shows that half of the ambient temperatures fall below 15°C and half fall above 15°C. At this point of forced cooling, the temperature is brought right down to -1°C, but it can be seen that the ambient temperature does not reach that point.

The box and whisker plot in Figure 23 show the spread of relative humidity each year, at different process stages within the pack houses. The data is also broken down at the precooler process stage, where the humidifier system is installed. It is illustrated in Figure 23 that average RH, at the precooler process stage, with the humidification system installed has the highest percentage RH every year. The figure also shows that the variances between the averages are smaller at the precooler process stage with the humidification system installed than the pack line and precooler process stage without the humidification system. This can be seen as the “box and whisker” is shorter at the precooler process stage with the humidifier.

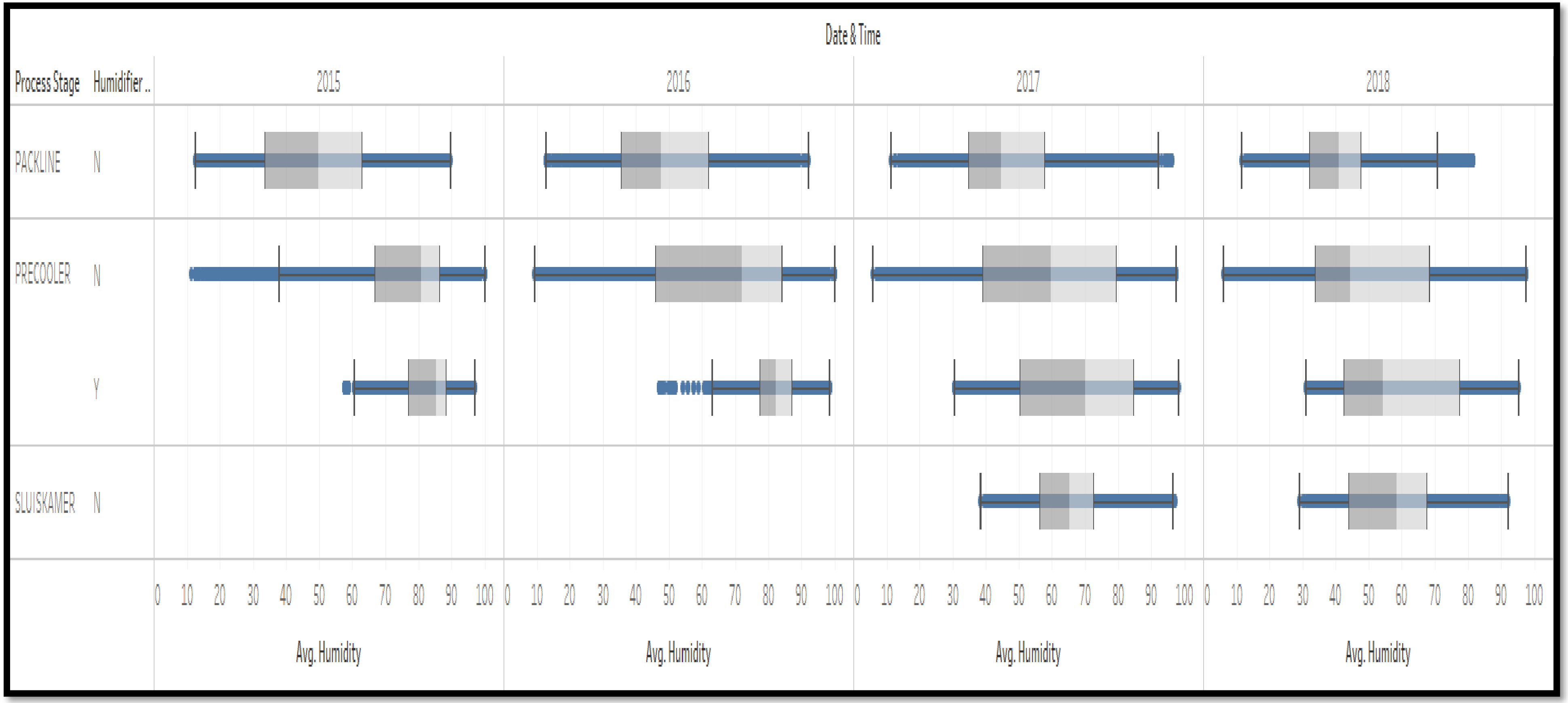

Figure 23: Box plot of average humidity for Humidifier Y/N broken down by Process Stage over 3 seasons.

Figure 24 maps out the average humidity and average temperature at the precooler process stage across the years for all seven pack houses. This view shows how the ambient temperature and humidity percentage look over time. Figure 24 shows that at Farm 1 pack house the average humidity in 2015 was 69.09% and increased to 81.81% with the installation of the humidifier. It stayed in the low 80s in 2016, but dropped to 67.47% in 2017 and 59.25% in 2018. This shows that the humidifier system may have experienced some problems in maintaining the high humidity percentage in 2017 and 2018. Figure 24 also shows that in 2015, the average temperature was below 20°C, but increased to temperatures above 20°C in 2018 across all pack houses. In some cases, at Farm 7 and Farm 3's pack houses, the average ambient temperature increases to 27.08°C and 26.99°C respectively.

		Date and time			
Farm Loc		2015	2016	2017	2018
FARM 1	Avg. Humidity	69,09 81,81	82,53	67,47	59,25
	Avg. Temperature	18,47 16,87	18,93	22,15	22,86
FARM 2	Avg. Humidity			59,62	51,99
	Avg. Temperature			20,88	24,26
FARM 3	Avg. Humidity	73,50	51,89	53,56	38,89
	Avg. Temperature	18,75	25,59	24,93	26,99
FARM 4	Avg. Humidity			57,89	39,64
	Avg. Temperature			21,56	26,12
FARM 5	Avg. Humidity	73,03	77,82	70,18	70,03
	Avg. Temperature	17,35	19,90	20,69	20,50
FARM 6	Avg. Humidity	77,88	77,40	68,11	63,46
	Avg. Temperature	16,63	19,58	21,01	21,85
FARM 7	Avg. Humidity		51,85	53,02	35,31
	Avg. Temperature		22,85	23,68	27,08

Humidifier Y/N
N
Y

Figure 24: Graph illustrating average relative humidity and average ambient temperature at the precooler process stage over the three seasons across the seven pack houses

Figure 25 maps out the average humidity and average temperature at the pack line process stage across the years for all seven pack houses. No humidifier was installed at this process stage. This view shows how the ambient temperature and humidity percentage look over time. Figure 25 shows that at Farm 1's pack house, the average humidity in 2015 was 50.64% and decreased to 46.54% in 2018. Figure 25 also shows that in 2015, the average temperature was below 25°C, but increased at most pack houses to temperatures above 25°C in 2018. In addition, Figure 25 shows that in 2018 Farm 7's average humidity dropped down right to 33.78%. Farm 7 had the second highest number of quality issues that were recorded.

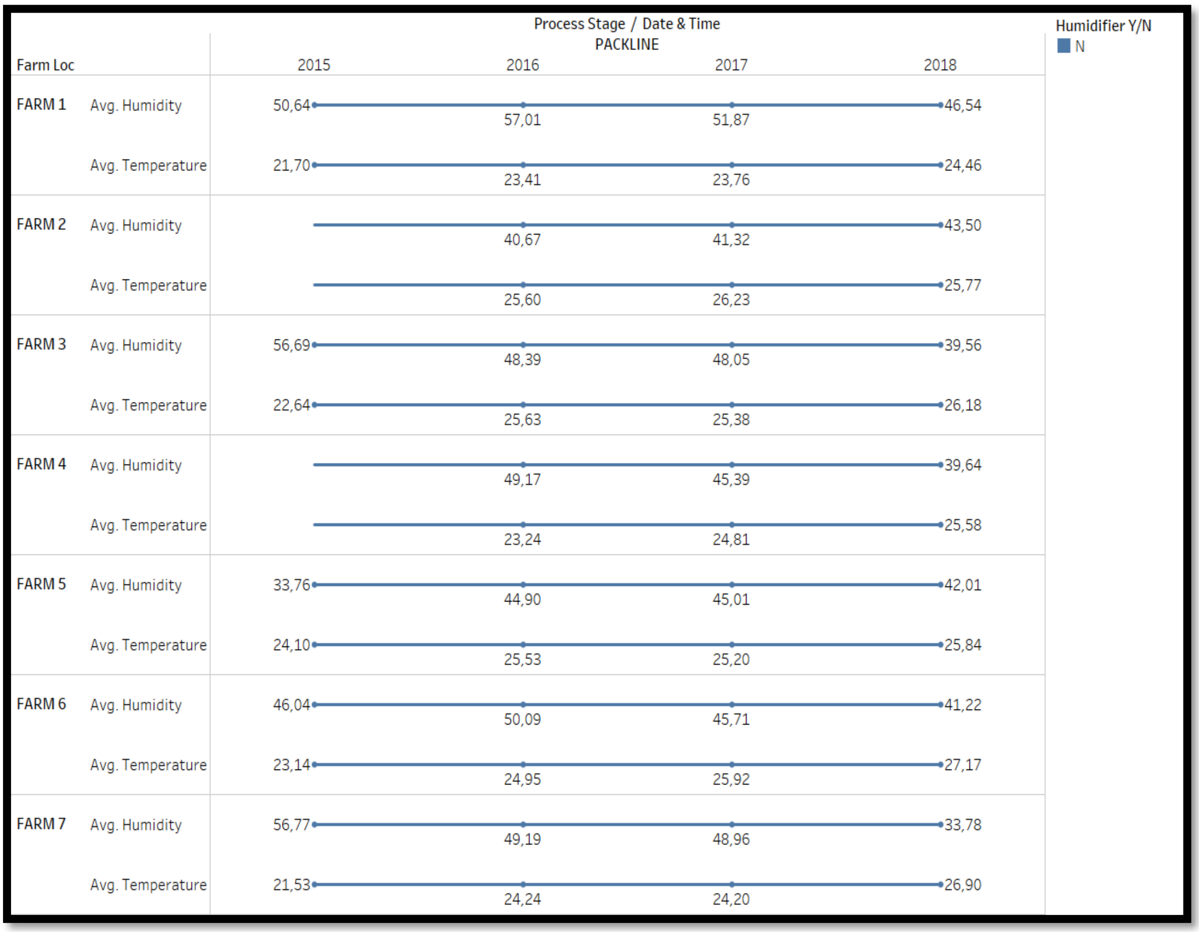

Figure 25: Average humidity and average temperature at the pack line process stage over the three seasons across the seven pack houses

Data at the Sluiskamer were only collected at two of the pack houses, namely Farm 1 and Farm 3 during the 2017-2018 season. This is shown in Figure 26. The average humidity at both pack houses is similar at percentages above 55%, but not close to the 95% that best practice recommends. The average temperature at Farm 3 was lower than that at Farm 1, namely 12.71°C in 2017 and 16°C in 2018 compared to Farm 1, at 13.38°C in 2017 and 20.33 in 2018.

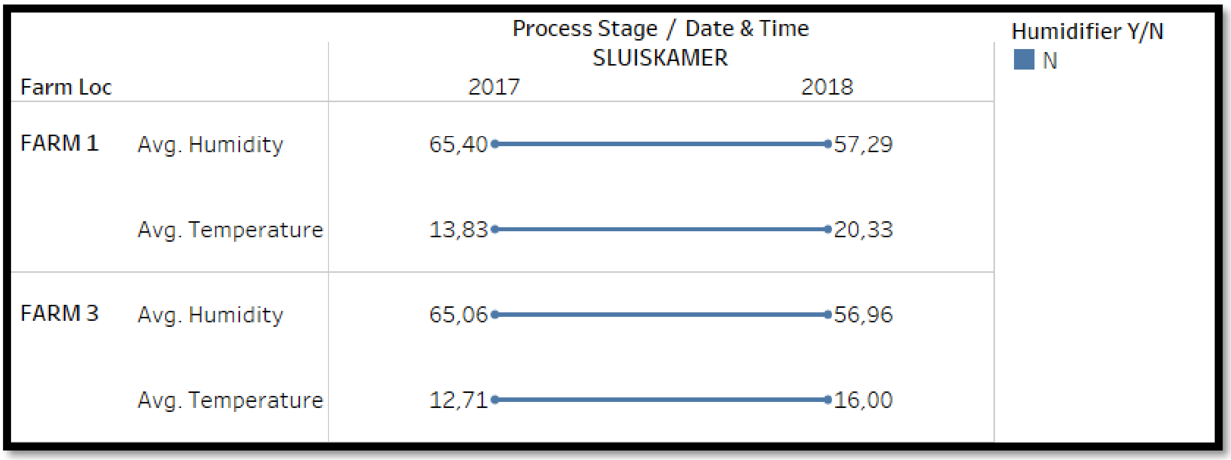

Figure 26: Average humidity and average temperature at the Sluiskamer process stage over the three seasons at Farm 1 and Farm 3

Table 15 shows the descriptive statistics of temperature at the pack line and pre-cool process stage at Farm 1. The mean temperature without the humidifier system installed is lower at 19.87°C and with the humidifier system installed; the mean temperature is 22.35°C. However, when looking at the specific process stage, it can be seen that at the precooler process, the mean temperature is lower, when compared to the pack line process stage, whether the humidifier system is installed or not. The statistical measure standard deviation (Std. Dev.) measures the spread of the data around the mean. The higher the standard deviation, the more spread out the data is. The standard deviation of temperature between the pack line process and the precooler process is pointed out in the orange block in table 15. It is seen that the standard deviation at the pack line (2.937) is lower than at the precooler (4.264). This means that the temperatures at the precooler is more spread out than at the pack line. The bottom half of table 15 further breaks down the pack line and precooler process stage comparing them to each other without the humidifier (N) and with the humidifier (Y). Although the pack line does not have a humidifier, the table is used to analyze the precooler with the humidifier against the same data of the precooler. This is identified when the amount of data points (N) is the same for pack line and precooler (N) and pack line and precooler (Y). When this comparison is done, the mean temperature at the precooler is found to be lower at 18.47°C and 20.97°C.

Table 15: Descriptive statistics of temperature at pack line and precooler at Farm 1 pack house

	Descriptive Statistics							
Effect	Level of Factor	Level of Factor	N	TEMPERATURE Mean	TEMPERATURE Std.Dev.	TEMPERATURE Std.Err	TEMPERATURE -95.00%	TEMPERATURE +95.00%
Total			48000	22.06764	3.913618	0.017863	22.03263	22.10265
HUMIDIFIER	N		5482	19.86968	3.200875	0.043231	19.78493	19.95443
HUMIDIFIER	Y		42518	22.35103	3.907333	0.018949	22.31389	22.38817
PROCESS STAGE	PACKLINE		24000	23.45025	2.937420	0.018961	23.41308	23.48741
PROCESS STAGE	PRECOOLER		24000	20.68504	4.263999	0.027524	20.63109	20.73899
HUMIDIFIER*PROCESS STAGE	N	PACKLINE	2741	21.27034	3.008957	0.057473	21.15765	21.38303
HUMIDIFIER*PROCESS STAGE	N	PRECOOLER	2741	18.46903	2.741532	0.052365	18.36635	18.57170
HUMIDIFIER*PROCESS STAGE	Y	PACKLINE	21259	23.73131	2.807541	0.019255	23.69357	23.76905
HUMIDIFIER*PROCESS STAGE	Y	PRECOOLER	21259	20.97076	4.340788	0.029771	20.91241	21.02911

In Figure 27, a box and whisker diagram of both average temperature versus average humidity broken down by humidifier system Y/N is shown. The average temperature is plotted on the x-axis and the average humidity is plotted on the y-axis. Plotting both these groups on the same graph allows the reader to spot any differences in the data quickly. The “upper hinge” is the data above the median and the “lower hinge” is below the median. These upper and lower hinges are shaded in light grey and dark grey, respectively. Comparing the average humidity of the data collected from the pack with and without the humidifier, the statistical data shows that the upper whisker or maximum average percent RH is experienced at the farm with the humidifier installed. The upper whisker is 82.53% with the humidifier versus 73.78% without the humidifier. The median or middle point of the average percent RH with the humidifier system is 74.64 versus 61.91 without the humidifier system. The lower whisker or minimum average percent RH is 59.25% with the humidifier system and 49.93% without the humidifier system. More average RH data points lie below the median for the farm with the humidifier system. This is seen with more, darker grey shaded at the lower end of the box and whisker for average RH with a humidifier system installed. Whereas, the farms without the humidifier, have a somewhat equal share of data points lying above and below the median. This is seen where almost an equal amount of light grey and dark grey is shaded in the box and whisker of average RH without humidifiers. The upper whisker and average temperature of farms with humidifiers is 22.86°C, whereas the upper whisker and average temperature of farms without humidifiers is 24.47°C. More data lies below the median of 22.42°C for farms without humidifiers, as can be seen with more, darker grey shaded in the lower part of the box and whisker. This shows that more of the average temperature, data points, lie below 22.42°C for farms without humidifiers. However, the whisker is longer between the lower hinge and lower whisker for farms without humidifiers than farms with humidifiers. This shows that there is more variation between lowest temperatures and the bottom quarter of average temperatures at farms without humidifiers. This can be interpreted as there is less control of temperatures at farms without humidifiers than farms with humidifiers.

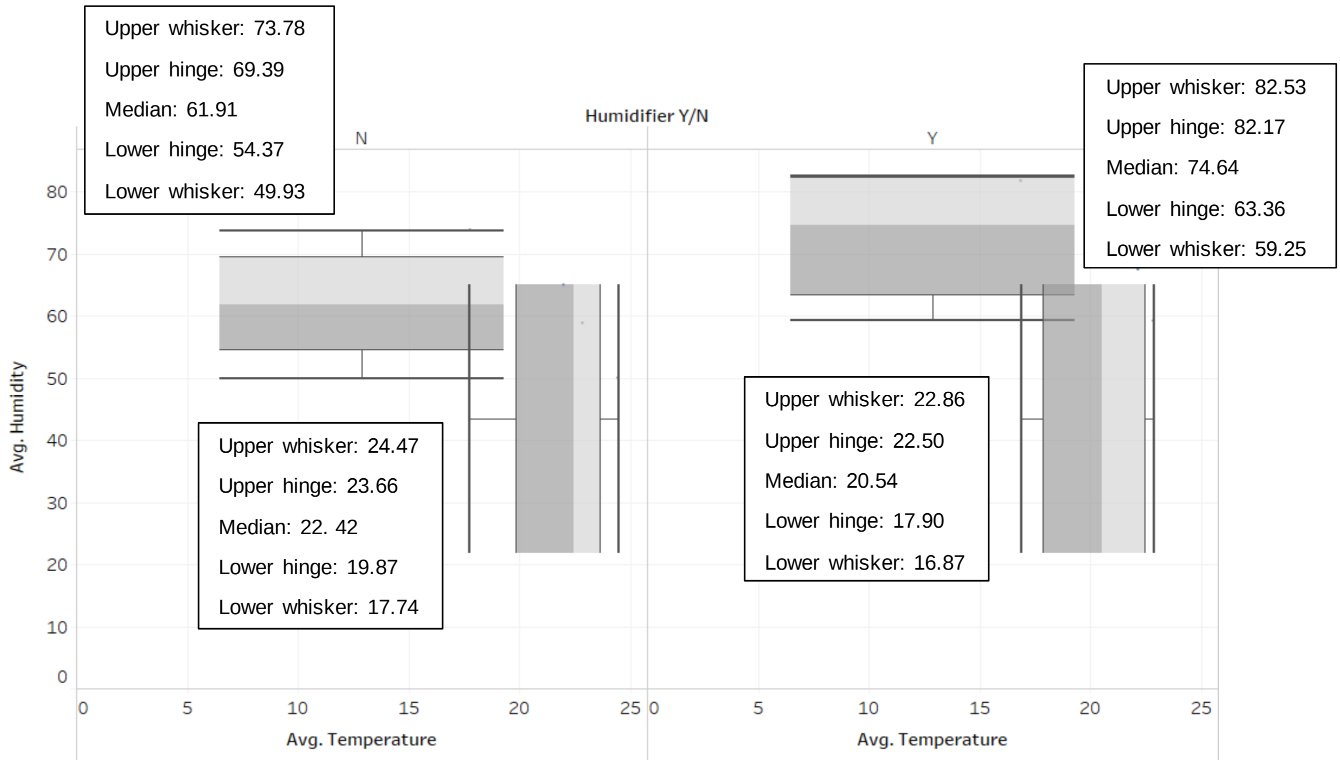

Figure 27: Box and whisker plot of average temperature versus average humidity broken down by humidifier system Y/N.

4.4.2 Comparison of trend lines at farms with humidifier (Y) and without humidifier (N) at the precooler

In this section, the data at the precooler process stage is analyzed. This is done, because as stated in the methodology section of this research, the humidifier system was only installed at the precooler process stage at Farm 1. In Figure 28, data was analyzed just at the precooler process stage to identify if there was a significant difference in relative humidity with or without the installation of the humidification system. It can clearly be seen that humidity without the humidifier is lower and the humidity is higher with the humidifier, at this process stage. However, to see whether there is a significant difference between the two an ANOVA test was conducted that revealed a p-value less than the significance level of 0.05. This means that at the precooler, there is significant difference in RH at the farm (Farm 1) with the humidifier system compared to farms without the humidifier system. The RH is significantly higher at Farm 1 than at the other farms at the precooler process stage. However, the maximum and minimum data points with the humidifier installed (circled in red) are wider than when there is no humidification system installed (circled in green). This is identified in the graph due to the wide and narrow spaces between the mean, which are the circles that the line in the graph is connected to.

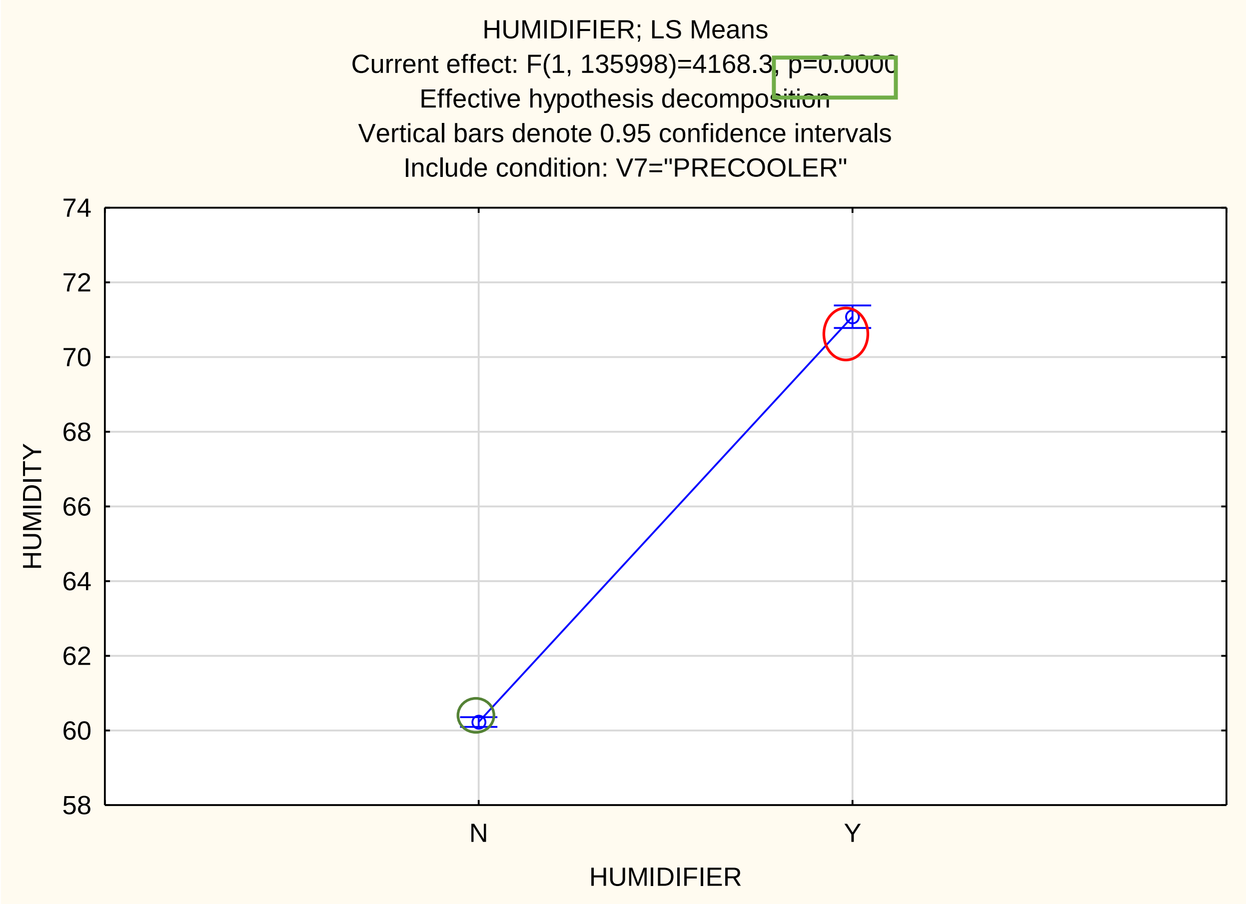

Figure 28: Graph showing the difference in relative humidity with and without the humidifier at the precooler process stage

The inferential statistical measures of the graph in Figure 28 are summarized in Table 16 and the descriptive statistical measures of Figure 28 are summarized in Table 17. Table 17 shows the intercept, F-value and p-value that shows that there is a significant difference in humidity with the humidifier (Y) and without the humidifier (N). This conclusion was made because the p-value resulted in a value less than 0.05. The statistical measure standard deviation (S) measures the spread of the data around the mean. The higher the S, the more spread out the data is. The standard error (SE/Std. Error) tells one how far the sample statistic (for example, the sample mean) deviates from the actual population mean. The larger the sample size, the smaller the SE (Jaggia & Kelly: 2020). The larger the sample size, the closer the sample mean is to the actual population mean. <u>This means that this sample data can make an inference about the population of table grapes' humidity with and without the humidification system installed.</u> In Table 17, the mean humidity without the humidifier is 60.23% and the mean humidity with the humidifier is 71.08%. The standard error without the humidifier is 0.07 and the standard error with the humidifier is 0.15. From Table 17, it can be seen that the standard error is very small. Therefore, this means that the results from this sample data can make an inference about the population of table grapes' humidity with and without a humidification system installed. The inference made is that with the installation of a humidifier at the precooler process stage, the humidity is higher. Without the humidifier system, the humidity is lower. Furthermore, the p-value (less than 0.05) reveals that this difference in humidity is significantly higher at the precooler stage, with the humidifier installed.

Table 16: Illustrating inferential statistical measures showing significance for relative humidity with and without the humidifier at the precooler process stage

Effect	Univariate Tests of Significance for HUMIDITY. Sigma-restricted parameterization Effective hypothesis decomposition Include condition: V7="PRECOOLER"				
	SS	Degree. of Freedom	MS	F	p
Intercept	309248333	1	309248333	609800.5	0.00
HUMIDIFIER	2113896	1	2113896	4168.3	0.00
Error	68968711	135998	507		

Table 17: Illustrating descriptive statistical measures showing relative humidity with and without the humidifier at the precooler process stage

Cell No.	HUMIDIFIER; LS Means Current effect: F(1, 135998)=4168.3, p=0.0000 Effective hypothesis decomposition Include condition: V7="PRECOOLER"					
	HUMIDIFIER	HUMIDITY Mean	HUMIDITY Std. Err	HUMIDITY -95.00%	HUMIDITY +95.00%	N
1	N	60.22605	0.066481	60.09575	60.35635	114741
2	Y	71.08232	0.154450	70.77960	71.38503	21259

In Figure 29, data was analyzed just at the precooler process stage to identify whether there was a significant difference in ambient temperature with or without the installation of the humidification system. It can clearly be seen that ambient temperature without the humidifier system is higher than when compared to the lower ambient temperature with the humidifier system at this process stage. However, to see if there is a significant difference between the two, an ANOVA test was conducted that revealed a p-value less than the significance level of 0.05. This means that at the precooler, there is significant difference in ambient temperature at the farm (Farm 1) with the humidifier against farms without the humidifier at the precooler process stage. The ambient temperature is significantly lower at Farm 1's precooler than at the other farms. However, the maximum and minimum data points with the humidifier system installed (circled in red) is wider than when there is no humidification system installed (circled in green). This is identified in the graph due to the wide and narrow spaces between the mean, which are the circles that the line in the graph is connected to.

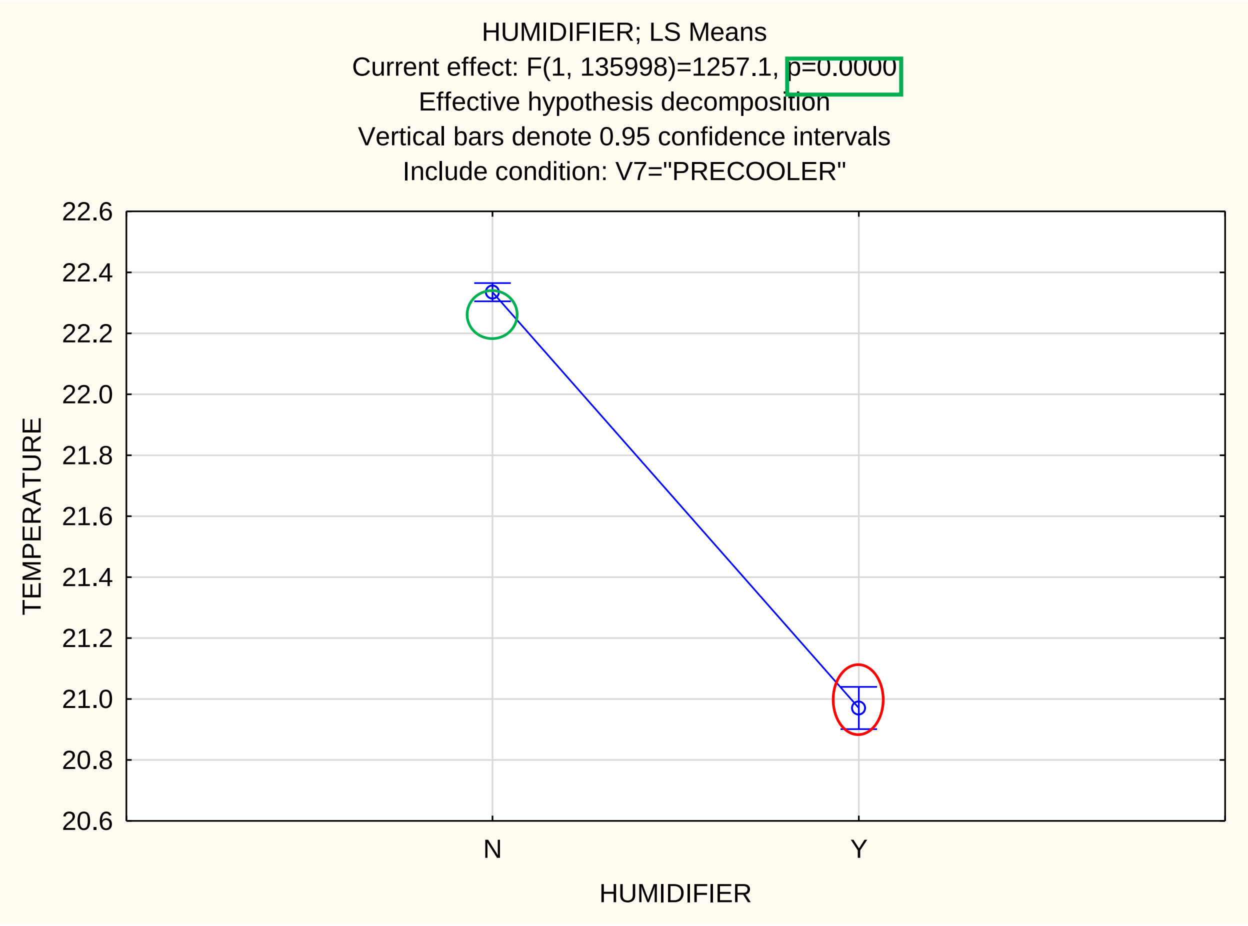

Figure 29: Graph showing the difference in ambient temperature with and without the humidifier at the precooler process stage

The inferential statistical measures of the graph in Figure 29 are summarized in Table 18 and the descriptive statistical measures of Figure 29 are summarized in Table 19. Table 18 shows the intercept, F-value and p-value that shows that there is a significant difference in ambient temperature with the humidifier (Y) and without the humidifier (N). This conclusion was made, because the p-value resulted in a value less than 0.05. The statistical measure standard deviation (S) measures the spread of the data around the mean. The higher the S, the more spread out the data is. The standard error (SE/Std. Error) tells one how far the sample statistic (for example, the sample mean) deviates from the actual population mean. The larger the sample size, the smaller the SE (Jaggia & Kelly: 2020). The larger the sample size, the closer the sample mean is to the actual population mean. As stated previously, this means that this sample data can make an inference about the population of table grapes' ambient temperature with and without the humidification system installed. In Table 19, the mean ambient temperature without the humidifier is 22.33°C and the mean ambient temperature with the humidifier is 20.97°C. The standard error without the humidifier is 0.02 and the standard error with the humidifier is 0.04. From Table 19, it can be seen that the standard error is very small. Therefore, this means that the results from this sample data can make an inference about the population of table grapes' ambient temperature with and without the humidification system installed. The inference made is that with the installation of the humidifier at the precooler process stage, the ambient temperature is lower. Without the humidifier, the ambient temperature is higher. Furthermore, the p-value (less than 0.05) reveals that this difference in ambient temperature is significantly lower at the precooler stage, with the humidifier installed.

Table 18: Illustrating statistical measures showing significance for ambient temperature with and without the humidifier at the precooler process stage

Effect	Univariate Tests of Significance for TEMPERATURE. Sigma-restricted parameterization Effective hypothesis decomposition Include condition: V7="PRECOOLER"				
	SS	Degree. of Freedom	MS	F	p
Intercept	33636615	1	33636615	1266818	0.00
HUMIDIFIER	33377	1	33377	1257	0.00
Error	3611024	135998	27		

Table 19: Illustrating descriptive statistical measures showing ambient temperature with and without the humidifier at the precooler process stage

Cell No.	HUMIDIFIER; LS Means Current effect: F(1, 135998)=1257.1, p=0.0000 Effective hypothesis decomposition Include condition: V7="PRECOOLER"					
	HUMIDIFIER	TEMPERATURE Mean	TEMPERATURE Std. Err	TEMPERATURE -95.00%	TEMPERATURE 95.00%	N
1	N	22.33492	0.015212	22.30510	22.36473	114741
2	Y	20.97076	0.035341	20.90149	21.04003	21259

4.4.3 Comparison of the trend lines at farm 1 with humidifier (Y) and without humidifier (N)

In this section, the data is analyzed further just focusing on Farm 1. As stated in the methodology section, Farm 1 had the humidifier system installed in December 2015. Prior to this, Farm 1 operated for some time without the humidifier system. This section focuses just on Farm 1 to see whether the humidifier system had any significant relationship between temperature and humidity before and after the implementation of the humidifier system. In Figure 30, a scatterplot and regression line, evaluating ambient temperature and relative humidity, were drawn for Farm 1 without the humidifier. It is seen that the data is quite scattered around the mean. This shows that the ambient temperature and RH, at Farm 1 without the humidifier, fluctuates wildly around the mean and shows that the differences in average mean temperature and the differences in RH, are wide and not close to the overall mean. The temperatures and humidity at Farm 1 without the humidifier are not very stable. The – 0.67 (r value circled in purple) is the correlation coefficient with the value of the slope of the regression line being -5.0512 (circled in orange at the top of the graph). The negative slope means an inverse relationship between temperature and humidity.

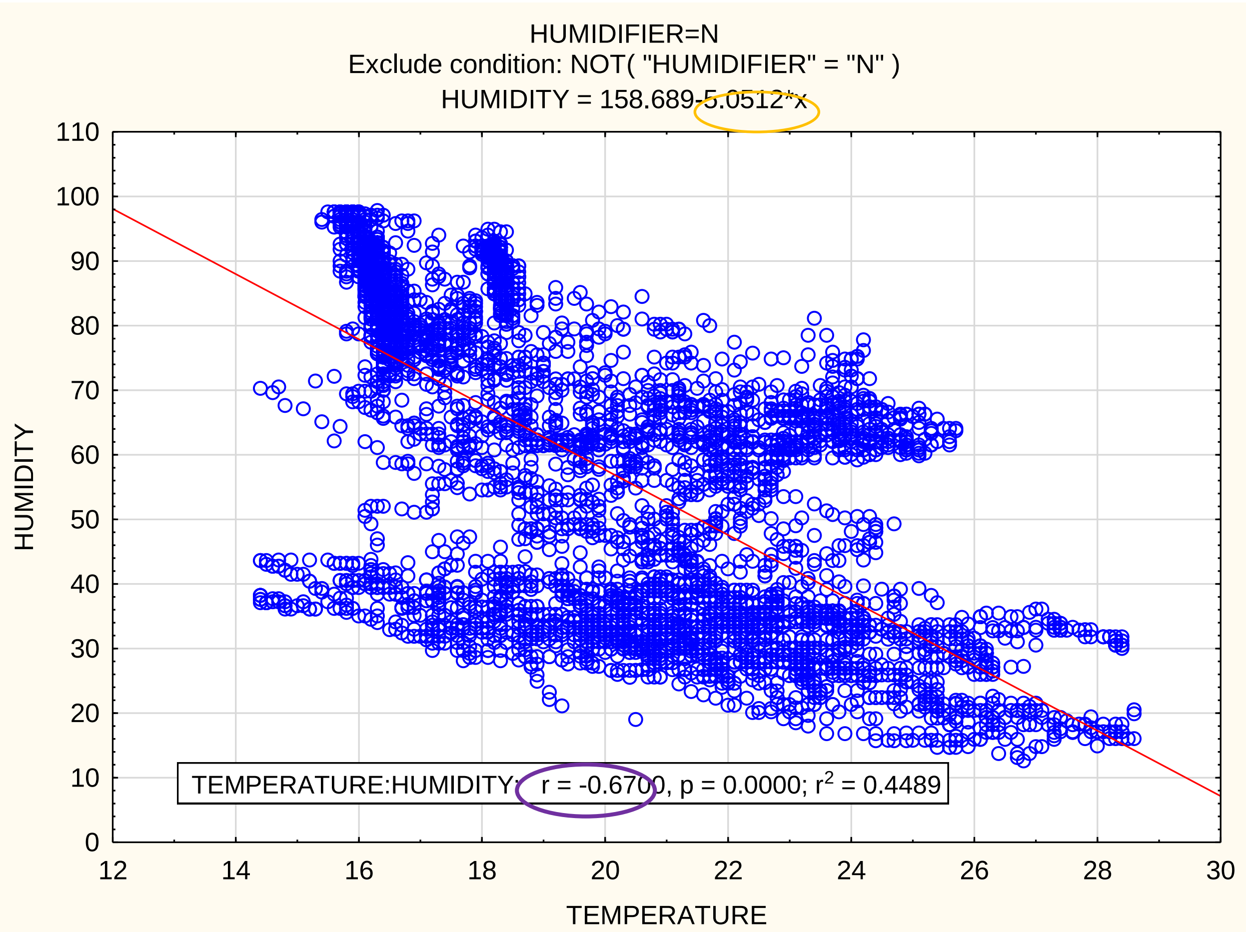

Figure 30: Graphed scatter plot and regression line of Farm 1 without the humidifier (N)

In Figure 31, a scatterplot and regression line, evaluating ambient temperature and relative humidity, were drawn for Farm 1 with the humidifier. It is seen that the data is gathered quite closely around the mean. This shows that the ambient temperature and RH, at Farm 1 with the humidifier, does not fluctuate wildly around the mean and shows that the differences in average mean temperature and the differences in average RH are close to the overall mean. There are more stable temperatures and humidity at Farm 1 with the humidifier. The – 0.6 (r value circled in purple) is the slope of the regression line. The negative slope means an inverse relationship between temperature and humidity.

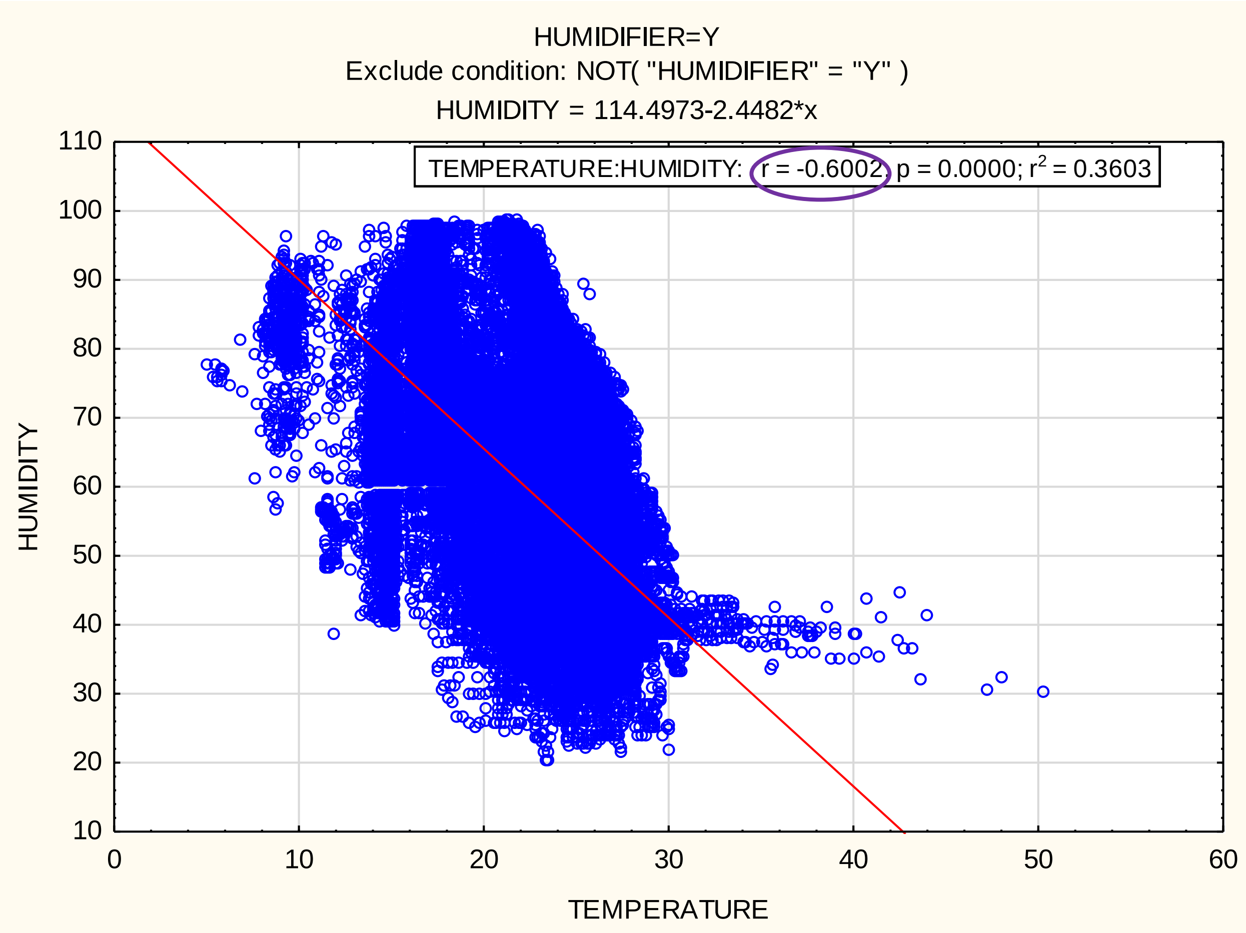

Figure 31: Graphed scatter plot and regression line with humidifier (Y)

To show whether there is a significant difference in the ambient temperatures and RH with or without the humidifier at Farm 1, the two regression lines were plotted onto one graph. This can be seen in Figure 32. In figure 32, the vertical line shows where the overall mean temperature is. The overall mean temperature, namely 21.4°C (This was calculated in Statistica® and the detail to getting this value is not provided). The means for humidity is where the vertical line crosses the regression lines for Humidifier =N and Humidifier =Y. This is the logical position where the two regression lines should be investigated to see if the relative humidity differs significantly. Thus, an ANCOVA (Analysis of Covariance) was done where humidity is the response variable (dependent variable) and temperature is the covariate (independent variable). As Dunn & Clark (1987) describe, an ANCOVA is the analyses of several regressions due to different categories. Here the categories are Humidifier =N and Humidifier =Y.

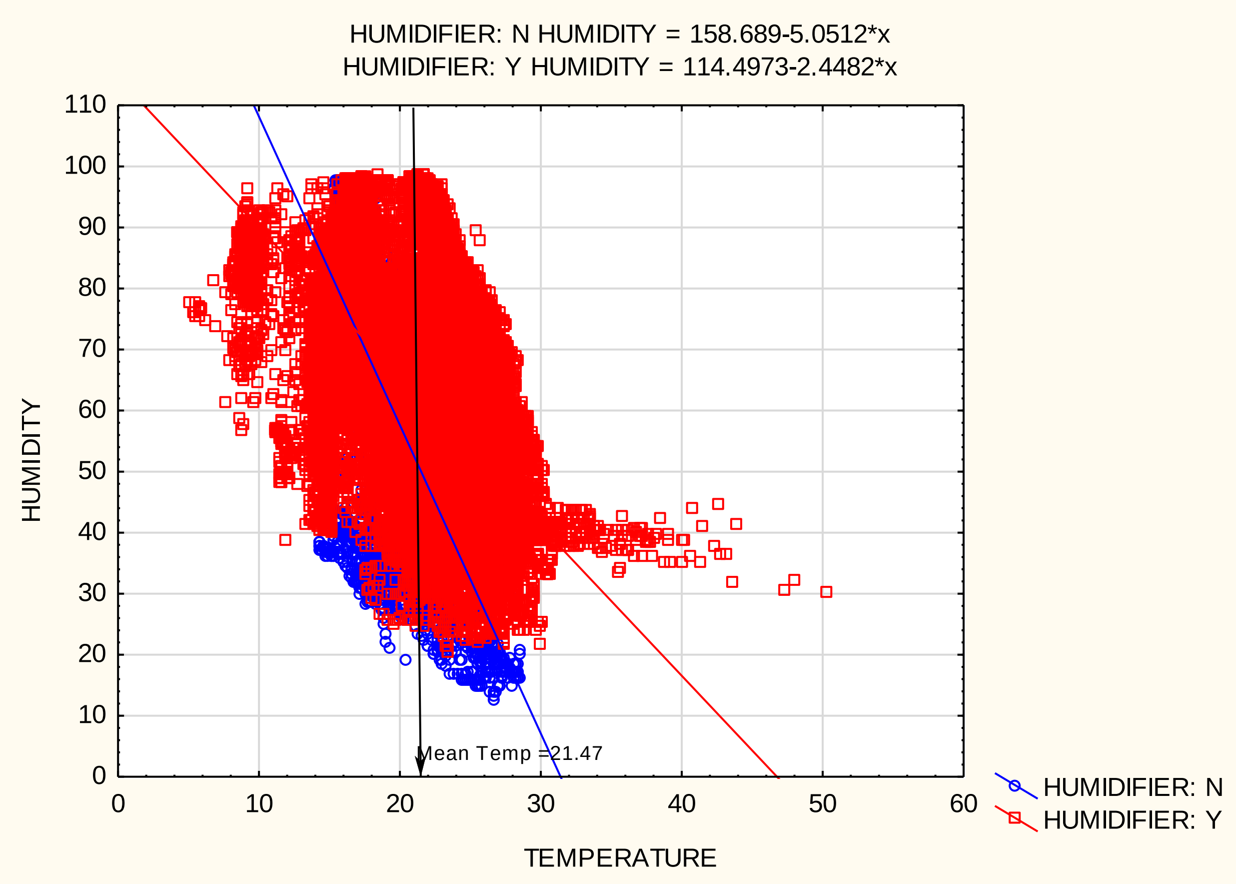

Figure 32: Graphed scatter plots, regression lines and mean of Farm 1 with and without the humidifier

Table 20 shows the results from the ANCOVA. The results show that the humidity is significantly related to temperature with F= 31005.7 and with p-value ($p<0.001$). This means that the humidity decreases significantly for both regression lines, i.e. the humidity significantly influences the temperature. The two levels of the Humidifier are also significantly different, since F= 1298.1 with p-value $p<0.001$. To put it simply, with the humidifier there is a significant difference in ambient temperature (lower) and significant difference in relative humidity (higher) at Farm 1, after the implementation of the humidifier.

Table 20: Univariate Tests of Significance for HUMIDITY (DATA FARM1)

Effect	Univariate Tests of Significance for HUMIDITY (DATA FARM1) Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 15.0657				
	SS	Degr. of	MS	F	p
Intercept	28041619	1	28041619	123544.0	0.00
HUMIDIFIER	294641	1	294641	1298.1	0.00
TEMPERATURE	7037567	1	7037567	31005.7	0.00
Error	12710015	55997	227		

4.4.4 Where does the difference lie

In sections 4.4.1, 4.4.2 and 4.4.3 the data compared the relative humidity and ambient temperatures across different areas of the pack house. These sections investigated the ambient temperature and RH across all farms at different process stages and specifically at the precooler process stage and thereafter at Farm 1. The results from these sections showed that there is a significant difference in the temperatures and relative humidity. However, in order to provide more detail, the Bonferroni test shows where the differences lie. The Bonferroni is similar to the ANCOVA where it conducts an analysis of the independent variable on the dependent variable and measures the means of the dependent variable across multiple levels of the independent variable (Saunders et al., 2003:201).

In Figure 33 and Figure 34, the statistical program SAS® was used to generate the Bonferroni test and results, through a General Linear Model (GLM) procedure. Figure 33 shows the Bonferonni test for temperature across all farms. The Bonferonni test groups all similar means into one group, represented by the A to F alphabet. In this study, if the means are similar, the farms will be grouped under the same alphabet. The test also arranges the scored means from highest to lowest. It can be seen in Figure 33 that Farm 4 overall, experiences the highest temperatures. Farm 4 and Farm 2 are both grouped in Bon grouping A, which means that there is not a big difference in their average temperatures. The rest of the farms have all been grouped in different Bon groupings, which shows that their average temperatures are all different. It is also seen through the Bon grouping that Farm 1 experiences the lowest temperatures on average. As most of the groups are not grouped together, this shows that there is variation in the temperatures across these farms, indicating a lack of temperature control.

The GLM Procedure

Bonferroni (Dunn) t Tests for **TEMPERATURE**

NOTE: This test controls the Type I experiment wise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	303993
Error Mean Square	22.04328
Critical Value of t	3.03810
Minimum Significant Difference	0.1009
Harmonic Mean of Cell Sizes	39932.09

NOTE: Cell sizes are not equal.

Means with the same letter are not significantly different.

Bon Grouping	Mean	N	FARM_LOC
A	24.84549	32000	FARM 4
A			
A	24.81245	24000	FARM 2
B	24.25617	40000	FARM 7
C	23.34027	56000	FARM 3
D	22.70991	48000	FARM 6
E	22.53635	48000	FARM 5
F	21.47020	56000	FARM 1

Figure 33: Bonferroni test (Temperature) at seven pack houses

Figure 34 shows the Bonferonni test for relative humidity across all farms. As stated above, the Bonferonni test groups all similar means into one group. If the means are similar, the farms will be grouped under the same alphabet. The test also arranges the scored means from highest to lowest. It can be seen in Figure 34 that Farm 1 overall, experiences the highest relative humidity, on average. Farm 4 experiences the lowest humidity on average. All of the farms have all been grouped in different Bon groupings, which shows that their average RH are all different. As most of the groups are not grouped together, this shows that there is variation in the relative humidity across all these farms, showing a lack of control of RH.

The GLM Procedure

Bonferroni (Dunn) t Tests for **HUMIDITY**

NOTE: This test controls the Type I experiment wise error rate, but it generally has a higher Type II error rate than REGWQ.

Alpha	0.05
Error Degrees of Freedom	303993
Error Mean Square	383.7371
Critical Value of t	3.03810
Minimum Significant Difference	0.4212
Harmonic Mean of Cell Sizes	39932.09

NOTE: Cell sizes are not equal.

Means with the same letter are not significantly different.

Bon Grouping	Mean	N	FARM_LOC
A	61.1963	56000	FARM 1
B	58.8021	48000	FARM 6
C	57.5942	48000	FARM 5
D	52.1445	56000	FARM 3
E	48.0748	40000	FARM 7
F	46.4801	24000	FARM 2
G	45.7182	32000	FARM 4

Figure 34: Bonferroni test (Relative Humidity) at seven pack houses

4.5 Relationship between quality messages and pack locations

In this section the quality of the table grapes are analysed. This was done using data set 2, which showed the quality messages that were collected at the port of destination (POD).

In Table 21, it can be seen that the total number of quality issues identified were 2339. It is seen that Farm 1 has the lowest quality messages related to it. Farm 1 had 201 recorded quality problems, whereas Farm 6 had the highest frequency of quality issues (481). In total, Farm 1 contributed 8.59% (201/2339) to the number of issues experienced and Farm 6 contributed 20.56% (481/2339). This table also shows that Farm 2 is a close second to the lowest counted quality issues.

Table 21: Showing the frequency of quality messages related to the pack location (Farms)

	2-Way Summary Table: Observed Frequencies (DATAX QUALITY 20200122) Marked cells have counts > 10							
qc_message	pack_location FARM 1	pack_location FARM 2	pack_location FARM 3	pack_location FARM 4	pack_location FARM 5	pack_location FARM 6	pack_location FARM 7	Row Totals
BLEMISHES	6	1	0	1	1	22	0	31
POOR SNIPPING	2	23	0	6	9	21	15	76
BRUISING	38	14	26	146	60	95	56	435
DECAY	2	17	15	37	19	57	28	175
POOR COLOUR	0	8	0	24	4	19	5	60
SPLITS-CONDENSATION	1	0	27	45	0	12	21	106
DECAY-SPLITS	1	20	39	7	25	44	7	143
DRY STEMS	21	10	36	7	0	12	3	89
SPILTS-CONDENSATION	29	13	55	10	6	11	37	161
BROWNING	39	46	48	121	74	62	163	553
WATER BERRIES	0	0	28	0	0	0	0	28
SHATTER	51	22	11	10	56	3	0	153
SO2 BURN	7	7	20	0	34	0	28	96
RUB MARKS	0	0	0	2	0	6	3	11
LOW BRIX	2	14	0	13	3	0	0	32
SUNBURN	0	0	9	3	0	0	0	12
GLASSY FRUIT	0	0	0	3	2	0	0	5
DECAY-SLIP SKIN	0	0	0	1	3	116	2	122
DECAY-STB	0	0	0	0	0	0	19	19
DECAY-CONDENSATION	2	0	0	0	0	0	0	2
SPIDER WEB	0	3	0	0	0	0	0	3
SHRIVEL	0	0	0	3	0	1	0	4
SOFT FRUIT	0	1	0	0	0	0	0	1
DECAY-BOTRITIS	0	9	2	5	0	0	0	16
MRL	0	0	0	0	4	0	0	4
DECAY-SOUR ROT	0	2	0	0	0	0	0	2
Totals	201	210	316	444	300	481	387	2339

To see if there is a significantly lower number of quality issues experienced at Farm 1 compared to all of the other farms (pack locations), a Chi squared test was done. The results from this test can be seen in table 22. The Chi-squared test revealed a p value p=0.00000001 which is less than the significance level of 0.05. This therefore says that, there is a significantly lower number of quality issues that are connected to Farm 1 than at any other farms.

Table 22: Chi squared test showing significance of quality problems at Farm 1 compared to the rest

Statistic	Statistics: qc_message(26) x pack_location		
	Chi-square	df	p
Pearson Chi-square	2052.457	df=150	p=0.0000
M-L Chi-square	1817.884	df=150	p=0.0000

In Table 23, the quality messages, associated with the various varieties and pack locations (farms), were **counted** and broken down to show claim type 0 and 5 (where “0” = claim with financial impact and “5” = logistical claim with financial impact). By counting the QC messages, this shows the number of instances a particular message was connected to a certain pack location. The data was sorted from highest to lowest to show what quality issues were experienced most frequently (from left to right of the grand totals in the last row) and the pack house that experienced the highest number of quality issues (top to bottom of the grand totals in the last column).

Four of the seven pack houses encountered a claim type “5”. This is a logistical claim that Company Y has to pay for. Thirty-three (7+13+7+6) of the 654 quality issues were due to a logistical claim (5.05%). The balance of 94.95% did have a financial impact, but were not due to logistical problems.

Table 23: Various quality issues and the associated pack locations with financial impact claims (0 and 5).

	Qc Message / Claim Type															
	BROWNING	DECAY	BRUISING	SPLITS-CO..	NO QC MSG		DRY STEMS	BLEMISHES	DECAY-SP..	SHATTER	SO2 BURN	DECAY-BO..	POOR COL..	POOR SNI..	MRL	Grand Total
Pack Location	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	
FARM 6		53	30	12	6	7	7	22	24				7			168
FARM 7	64	14		6	8	13	2		1		7			5		120
FARM 3	11	2	21	14	20	7	16					2				93
FARM 4	6	16	9	35	4	6	4		7			5				92
FARM 2	46		4		1		8	1		20		9				89
FARM 5			8		25			1		6	16				4	60
FARM 1	12		10		3		1	6								32
Grand Total	139	85	82	67	67	33	38	30	32	26	23	16	7	5	4	654

Table 24 tabulates the various quality problems relating to volume distributed. The table grouped the volumes and quality concerns that were experienced over the three seasons. The table also includes table grapes that were of “good condition”. These grapes had no quality concerns. It is seen that over the three grape seasons, 92.35% of the grapes distributed from

Company Y were in good condition. This means that 7.65% of the grapes were of concerning quality. From Table 20, Farm 1 contributed 8.59% to the total number of issues and Farm 6 contributed 20.56% (481/2339).

Table 24: Showing total volume distributed over the three season and associated quality messages

Quality Messages	**Sum of Container Volume**
GOOD CONDITION	92.35%
BROWNING	1.78%
BRUISING	1.36%
SPLITS-CONDENSATION	0.84%
SHATTER	0.56%
DECAY	0.54%
DECAY-SPLITS	0.50%
DECAY-SLIP SKIN	0.37%
DRY STEMS	0.36%
SO2 BURN	0.32%
POOR SNIPPING	0.23%
Other	0.78%
Grand Total	**100.00%**

Table 25, a count of QC issues related to specific varietals was recorded. The top three varietals and quality issues are highlighted in yellow. The top three varietals that encountered the largest number of quality issues were the Thompson seedless, Flame seedless and Midnight beauty respectively. The three most common quality problems faced were browning, bruising and splits-condensation. Based on the literature previously referenced, these three most commonly encountered quality issues are mostly due to low humidity and corresponding moisture loss. Low humidity causes the surrounding atmosphere to absorb moisture from the fruit, which dries the fruit and its parts such as the stem causing browning.

Table 25: Showing grape varietals and associated quality issues

	THOMPSON SEEDLESS	FLAME SEEDLESS	MIDNIGHT BEAUTY	MELODY	SUGRAONE	PRIME	SABLE SEEDLESS	RALLY	EARLY SWEET	Grand Total
BROWNING	373				24	57			53	553
BRUISING	269		4		53	49			14	435
SPLITS-CONDENSATION	9	213	28	9						267
DECAY	31	22	29	48		1	28			175
SHATTER			16		58		47	32		153
DECAY-SPLITS		16	70					19		143
DECAY-SLIP SKIN			4	118						122
SO2 BURN		7					7	41		96
DRY STEMS		4	32	5	2	23	1	20		89
POOR SNIPPING	10		43				16	2		76
POOR COLOUR		7	12				17			60
Grand Total	692	269	238	180	137	130	116	114	67	2169

To evaluate the quality issues in terms of volumes affected, Table 26 shows the total volume of table grapes with quality issues that were dispatched over the 2015-2018 period, from the various farms (including shipments with "no QC message"). "No QC message" means that quality issues were detected, but the specific message was not recorded. It is important to show this, because these are still quality issues and that can furthermore cause stock to be rejected. Five percent (5.0%) of all the quality issues that were identified at the port of destination were linked back to Farm 1's pack house. This is the lowest percentage of quality issues picked up. The highest percentage of issues were again linked back to Farm 6's pack house at 23.7% of the total volume shipped. If value was added to the table grapes that were shipped, for example, R1/kg (this may be extreme, but it is just to provide some context to the seriousness of the quality issues and the financial impact that it could have against Company Y and various other stakeholders). If 8 911 962 kilograms were found to have quality claims against it, using the above example of R1/kg would mean claims that would cost Company Y R 8 911 962. That is almost R9 million lost due to quality issues. Of the 17,001,540 kgs shipped by Company Y, 8 911 962 were found to have quality concerns.

Table 27 shows the total volume of table grapes with quality issues that were dispatched over the 2015-2018 period, from the various farms (excluding shipments with "no QC message"). The volumes that did not receive any quality control (QC) messages and the data prior to the installation of the humidifier system at Farm 1's pack house were excluded to show whether there would be major changes if only the specific QC messages were considered. The two farms that do show big differences are Farm 3 and Farm 5. Farm 3 drops from 14.7% to 9.8% and Farm 5 drops from 9.6% to 5.6%. This shows that more investigation at the POD needs to be done to provide more accurate QC feedback.

Table 26: Percentage (%) of total volume shipped that encountered quality problems (including "no QC message")

QC MESSAGE	FARM 1	FARM 2	FARM 3	FARM 4	FARM 5	FARM 6	FARM 7	SUM OF CONTAINER VOLUME
MRL	-	-	-	-	45,500	-	-	45,500
POOR SNIPPING	-	-	-	-	-	-	60,000	60,000
POOR COLOUR	-	-	-	-	-	81,600	-	81,600
DECAY-BOTRITIS	-	108,000	23,000	81,000	-	-	-	212,000
SO2 BURN	-	-	-	-	255,960	-	84,000	339,960
DECAY-SPLITS	-	-	-	110,160	-	283,200	11,500	404,860
SHATTER	-	324,000	-	-	90,880	-	-	414,880
BLEMISHES	69,000	16,200	-	-	16,728	327,000	-	428,928
DRY STEMS	16,200	129,600	259,200	64,800	-	113,400	32,400	615,600
SPLITS-CONDENSATION	-	-	161,000	460,300	-	144,000	72,000	837,300
BRUISING	115,000	64,710	230,000	142,560	93,600	347,520	-	993,390
DECAY	-	-	18,400	209,160	-	635,600	184,800	1,047,960
NO QC MESSAGE	48,600	9,600	441,096	151,920	353,380	178,968	282,100	1,465,664
BROWNING	198,240	750,480	178,200	74,400	-	-	763,000	1,964,320
GRAND TOTAL (including "NO QC MESSAGE")	**447,040**	**1,402,590**	**1,310,896**	**1,294,300**	**856,048**	**2,111,288**	**1,489,800**	**8,911,962**
% OF TOTAL QC CLAIMS	**5.0%**	**15.7%**	**14.7%**	**14.5%**	**9.6%**	**23.7%**	**16.7%**	**100.0%**

Table 27: Percentage (%) of total volume shipped that encountered quality problems (excluding "no QC message")

QC MESSAGE	FARM 1	FARM 2	FARM 3	FARM 4	FARM 5	FARM 6	FARM 7	SUM OF CONTAINER VOLUME
GRAND TOTAL (excluding "NO QC MESSAGE")	**398,440**	**1,392,990**	**869,800**	**1,142,380**	**502,668**	**1,932,320**	**1,207,700**	**8,911,962**
% OF TOTAL QC CLAIMS	**4.5%**	**15.6%**	**9.8%**	**12.8%**	**5.6%**	**21.7%**	**13.6%**	**100.0%**

Further investigation into the Farm 1 pack house QC issues are depicted in Table 28. This data shows the specific quality problems and the volume (kgs) of these issues. This data was for the period post installation of the humidifier (16 December 2015 to February 2018). The most common problem that was identified is browning with a volume of 198,240 kilograms of grapes over the three seasons. As mentioned previously, literature has revealed that low humidity and moisture loss leads to browning. In the previous section, data revealed that ambient temperature and relative humidity within the pack houses were unstable and varied across the three seasons. Even with the implementation if the humidification system, RH and temperature sometimes experience very high or very low values, which could mean some other cause of variance in ambient temperature and relative humidity.

Table 28: Volume of quality issues experienced by grapes packed at Farm 1 pack house post installing the humidifier system

FARM 1 Post Installation of Humidifier (16 Dec 2015)						
QC Message	07/12/2017	08/12/2017	21/12/2017	02/01/2018	16/01/2018	Container Volume (sum)
DRY STEMS				16,200		16,200
NO QC MSG			48,600			48,600
BLEMISHES		69,000				69,000
BRUISING		115,000				115,000
BROWNING	**16,200**				**182,040**	**198,240**
Grand Total	16,200	184,000	48,600	16,200	182,040	447,040

Figure 35 shows the quantity of grapes with claim type (0), the receiving country and the variety dispatched in 2017. The size of the circles shows the volume of the grapes with the colour of the circle representing the quality issue. Figure 35 shows that the Thompson seedless with browning issues and Melody with decay issues were both received in the Netherlands (NL). These two were the most commonly recorded issues and stand out, because of the size of the circles. Great Britain (GB) is the next country to receive large volumes of grapes with quality issues with varieties Prime (browning), Flame Seedless (splits-condensation) and Sable Seedless (shattering). From section 4.2, GB and NL are among the top four countries that Company Y exports to. This data shows where more emphasis needs to be placed in terms of which pack location exports to which country and Company Y can first invest in farms that supply to the biggest markets.

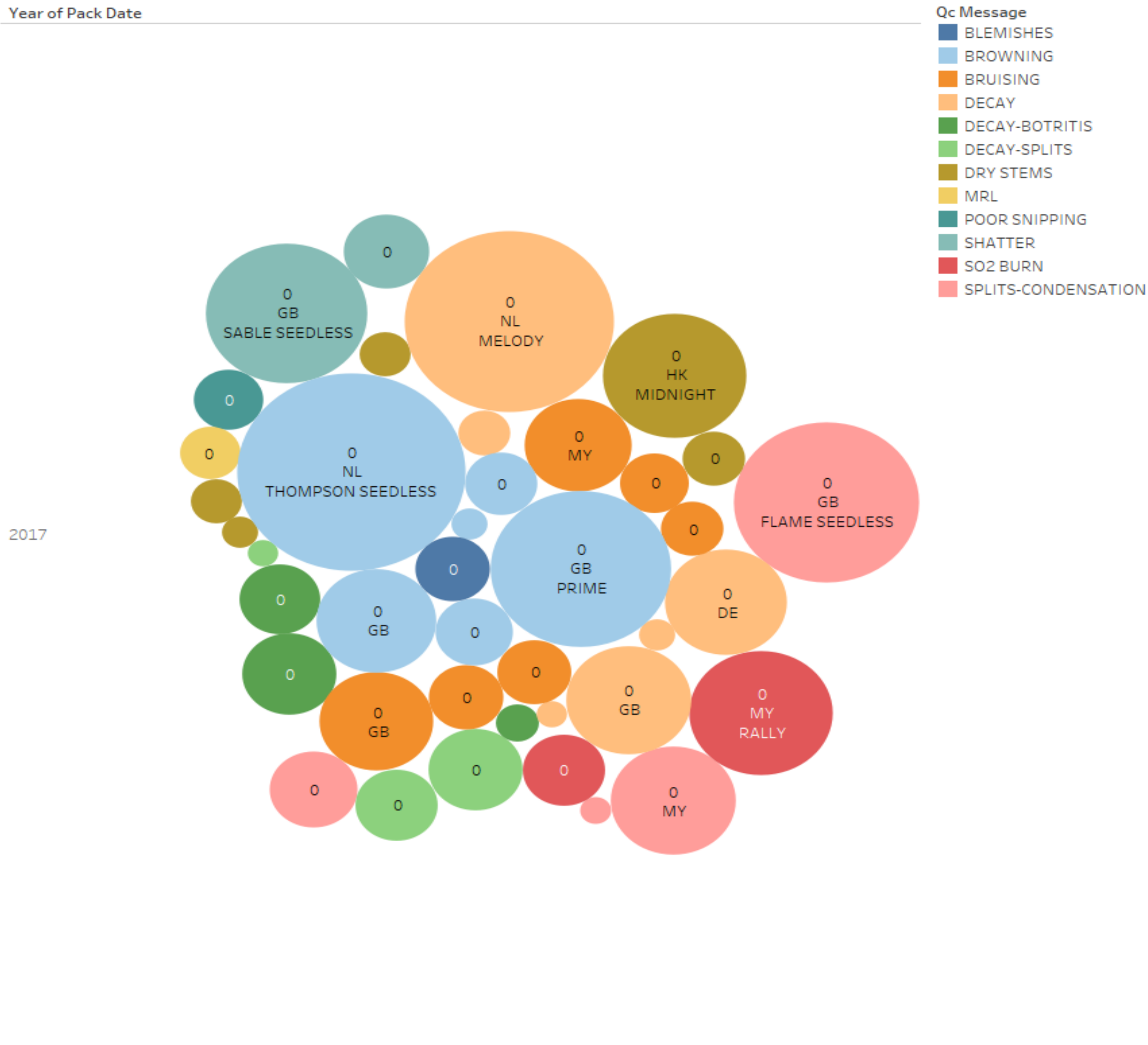

Figure 35: Claim Type, receiving country and variety broken down by pack date year (2017)
Colour shows details about QC Message. Size shows sum of container volume.

Figure 36 shows the quantity of grapes with claim type (0), the receiving country and the variety dispatched in 2018. The size of the circles shows the volume of the grapes and the colour of the circle shows the quality issue. Figure 36 again shows that the Thompson seedless was one of the varieties that faced problems with the most commonly experienced issue, i.e. bruising. This too was received in the Netherlands (NL). The second most commonly experienced issue was the browning of the Autumn Crisp variety exported to Great Britain (GB), which is again one of the top four countries that Company Y's table grapes are sold to. These two were the most commonly faced issues and stand out, because of the size of the circles. As previously advised, this data shows where more emphasis needs to be placed in terms of which pack location exports to which country and Company Y can first invest in farms that supply to the biggest markets.

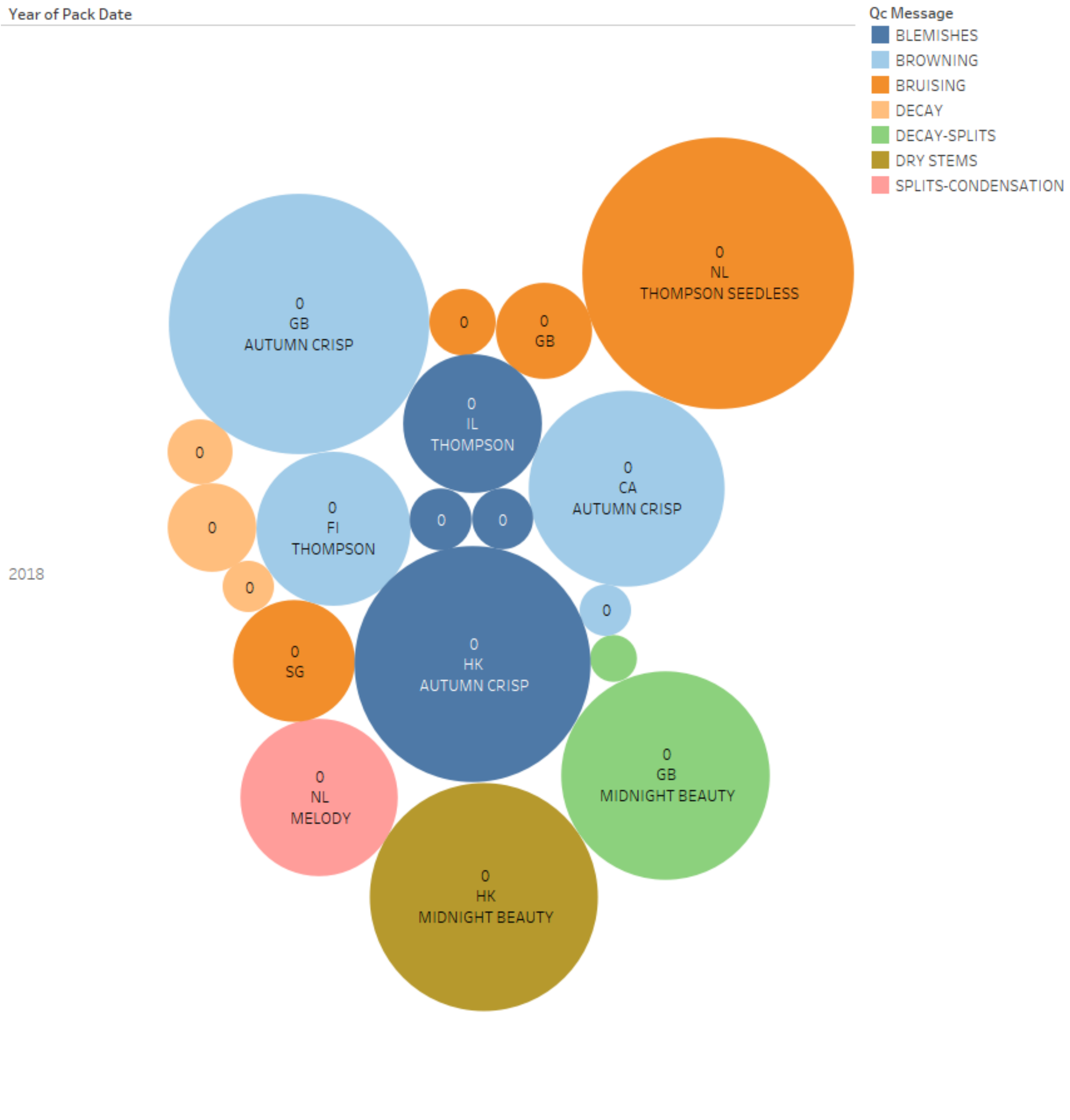

Figure 36: Claim Type, receiving country and variety broken down by pack date year (2018) Colour shows details about QC Message. Size shows sum of container volume

4.6 Conclusion

The fourth chapter of this thesis analysed data using inferential statistics, descriptive statistics and visual tools to make the data easy to interpret and provide definite conclusions to the study. Various data on quality, average temperature, average RH, Variance and countries that fruit was exported to provided underlying information that can be linked to qualitative data from the literature review within this study.

In both the ANOVA and ANCOVA tests done in this study, the p-value calculated is less than 0.0001. The Chi squared test, that tested quality at the farms also resulted in a p- value that was less than 0.05. According to Saunders *et al* (2003:160), if the p-value is less than the significance level, which is 0.05 in this study, the results are not by chance, but provide significant evidence about the relationship between variables. If the p-value is greater than the significance level, it is more likely that there is a weak relationship between the variables analysed. The results that were gathered in this chapter will be further interpreted in the chapter to follow.

CHAPTER 5: RESULTS AND INTERPRETATION

5.1 Introduction

Data analysed in the previous chapter is interpreted in the sections within this chapter. The chapter begins by highlighting significant data points and results from the study and thereafter provides an explanation of the results. The interpretation of the results provide basis for the conclusions made at the end of this study. Finally, the chapter finishes with a summary of the chapter and a conclusion.

5.2 Temperature and humidity results

As literature states, temperature and relative humidity have an inverse relationship (i.e. as one increases the other decreases). From the results gathered in Chapter 4, this was proven to be true between ambient temperature and RH at the pack locations (farms) that Company Y manages, in the Northern Cape of South Africa. The scatter plot graphs in section 4.3.1 of Chapter 4 showed the variance of the data and the relationship between ambient temperature and relative humidity. When temperature and humidity were plotted on individual graphs and when they were plotted against each other on the same graph, the relationship proved to be negative, i.e. as temperature increased, relative humidity decreased. This was shown by the negatively sloping trend line. The theory also shows that what Company X proposed (implementing humidifiers in table grape pack houses) is valid.

The main results produced from section 4.4.1 of this study show that the average ambient temperatures (without the humidification system) are higher, than the average ambient temperatures (with the humidification system). This can be seen in every season that the data was collected as summarised in Table 13 (section 4.4.1). Literature states that the best practice control of temperature inside a pack house is between 18°C and 25°C (Haasbroek, 2013). However, it was seen that temperatures often exceeds this maximum of 25°C. The results also showed that the average relative humidity (without the humidification system) was lower, than the average relative humidity (with the humidification system). This was experienced for the first two seasons (2016 and 2017), but in the last season (2018), the average humidity dropped at Farm 1 and Farm 5 was the one to experience the highest average temperature in that season. Farm 1’s RH was the second highest. This was summarised in Table 14 that was analysed in Chapter 4. The summary in these two tables showed that the humidification system maintained lower ambient temperatures and higher relative humidity percentages at the farm that it was installed in.

As stated in Chapter 4, the overall averages of RH and temperature represented in these tables were being measured across all the process stages. Therefore, more investigation was done at the various process stages, especially at the precooler where the humidifier was installed and furthermore at Farm 1, which was the only farm to have the humidifier installed.

When the standard deviation of ambient temperature was measured between the pack line and the precooler, it was found that the the standard deviation of the ambient temperature at the pack line (2.937) was lower than at the precooler (4.264). This showed that the spread of the temperatures at the precooler were more widely spread around the mean. This shows that temperatures are less controlled at the precooler process stage than at the pack line.

Section 4.4.2 analysed the RH and ambient temperatures at the precooler process stage. In this section, an ANOVA test of humidity at the precooler produced an F-value and p-value, where the p-value (0.00001) was less than the significance level of 0.05. That showed that there was a significant difference in humidity with the humidifier (Y) and without the humidifier (N). The inference made was that with the installation of the humidifier at the precooler process stage, the humidity is higher. Without the humidifier, the humidity is lower. Furthermore, the p-value (less than 0.05) reveals that this difference in humidity is significantly higher at the precooler stage, with the humidifier installed. Furthermore, an ANOVA was done to test the ambient temperature at the precooler process stage. The inference that was made is that with the installation of the humidifier at the precooler process stage, the ambient temperature is lower. Without the humidifier, the ambient temperature is higher. Furthermore, the p-value (less than 0.05) reveals that this difference in ambient temperature is significantly lower at the precooler stage, with the humidifier installed.

Section 4.4.3 analysed the relationship between Farm 1 before and after the implementation of the humidifier. Through an ANCOVA test done for RH and ambient temperature before the implementation of the humidifier against RH and ambient temperature after the implementation of the humidifier, the p-value that resulted was less than 0.001. This showed a significant relationship in RH at Farm 1 before and after the humidifier was installed and a significant relationship in temperature at Farm 1 before and after the humidifier was installed. With the humidifier, there was a significant difference in ambient temperature (lower) and significant difference in relative humidity (higher) at Farm 1, after the implementation of the humidifier.

Section 4.4.4 investigated where the differences in RH and temperature lie between the seven farms in this study. Through the Bon grouping, it was identified that Farm 1 experienced the lowest temperatures on average. Furthermore, overall, Farm 1 also experienced the highest relative humidity, on average. Farm 4 and Farm 2 experienced the highest temperatures on average and Farm 4 also experienced the lowest RH on average. All of the farms have all been grouped in different Bon groupings, which shows that their average RH are all different. As most of the groups are not grouped together for RH, this shows that there is variation in the relative humidity across all these farms, indicating a lack of control of RH. As most of the groups are not grouped together for temperature, this shows that there is variation in the temperatures across these farms indicating a lack of temperature control. As stated in the literature review, the Perishable Products Export Control Board (PPECB) describes the cold chain as the "seamless movement of fresh, chilled or frozen products, from the production area to the market, through various storage and transport mediums, without any change in the optimum storage temperature and relative humidity" (Cold Chain management, 2019). This should needs to be a focus in controlling temperature and humidity across their cold chain.

From the results achieved in section 4.4.1 to 4.4.4, the below hypothesis tests of this study were answered. With a resulting p-value of $p<0.0001$ to test Hypothesis 1, the null hypothesis of Hypothesis 1 is rejected. Therefore, there is a difference in the mean values of relative humidity percentages when the humidifier is installed versus the other pack houses where it is not installed.

Hypothesis 1:

H_0: There is no difference in the mean values of relative humidity percentages when the humidifier system is installed versus the other pack houses where it is not installed. (REJECTED)

H_A: There is a difference in the mean values of relative humidity percentages when the humidifier system is installed versus the other pack houses where it is not installed.

With a resulting p-value of $p<0.0001$ to test Hypothesis 2, the null hypothesis of Hypothesis 2 is rejected. Therefore, there is difference in the mean values of ambient temperatures when the humidifier system is installed versus the other pack houses where it is not installed.

Hypothesis 2:

H_0: There is no difference in the mean values of ambient temperatures when the humidifier system is installed versus the other pack houses where it is not installed. (REJECTED)

H_A: There is a difference in the mean values of ambient temperatures when the humidifier system is installed versus the other pack houses where it is not installed.

5.3 Quality results

The final section 4.5 of Chapter 4 investigated the relationship between the quality messages and the various farms. 7.65% of the grapes that were distributed by Company Y over the seasons, were of concerning quality. Farm 1 had the lowest quality messages related to it. Farm 6 had the highest quality messages related to it. Farm 1 contributed 8.59% to the total number of issues and Farm 6 contributed 20.56%. To see whether there was a significantly lower number of quality issues experienced at Farm 1 compared to all of the other farms (pack locations), a Chi squared test was done. The Chi-squared test revealed a p value $p=0.00000001$, which is less than the significance level of 0.05. In order to show that there is a significant difference in the means of the data, the means square of the p-value for the alternative hypothesis needs to be less than the significance level (0.05) (Dunn & Clark, 1987). With a resulting p-value of $p = 0.00000001$ to test Hypothesis 3, the null hypothesis is rejected. The number of quality problems is not the same at the farm where the humidifier system is installed and the other pack houses where it is not installed.

<u>Hypothesis 3:</u>

H_0: The number of quality problems is the same at the farm where the humidifier system is installed and the other pack houses where it is not installed. (REJECTED)

H_A: The number of quality problems is not the same at the farm where the humidifier system is installed and the other pack houses where it is not installed.

This data analysis revealed that Farm 6 experienced the highest number of quality issues and browning was recorded as the highest quality issue experienced throughout the research period. In addition, the Thompson seedless variety had highest number of quality issues.

5.4 Summary

Based on the literature, the best temporary storage conditions that are recommended for table grapes to be stored at, is a temperature of -0.5°C to 1.5°C and a relative humidity of 90%-95%. The results from the data analysis showed that Farm 1 had the lowest quality control issues over the three seasons. It also showed that higher humidity and lower temperatures were experienced at Farm 1 than most of the other pack houses. At Farm 1, temperature and humidity looked to be more stable, however, the data also reveals that ambient temperature and relative humidity are nowhere near the values they need to be in order to distribute the best quality grapes.

At different process stages, ambient temperature and relative humidity need to be controlled within a range of temperature and humidity requirements, but the data reveals that over the three seasons, there were many variations in the conditions.

From the data that was collected and analysed, inferential statistics reveal that the null hypotheses for Hypothesis 1 and Hypothesis 2 were rejected. The association showed a significant relationship in ambient temperature with and without the humidifier and a significant relationship in relative humidity with and without the humidifier. Temperature and RH move in opposite directions. Furthermore, there is a reduction in quality issues, post-harvest, through the implementation of the humidification system.

The data revealed that the majority of quality concerns were from pack houses where the temperatures were high and the humidity was low. Pack houses such as Farm 6 and Farm 7 showed that the little control of the temperature and humidity variables can cause financial losses due to the quality issues that were picked up. These two pack houses were also the two of the four pack houses that caused logistical financial losses. Farm 1 was shown to have the lowest percentage of quality concerns and therefore financial impact. Furthermore, through the Chi squared test, it was revealed that there is a significant relationship between the quality of grapes at farms with and without the humidification system. The number of quality problems is not the same at the farm where the humidifier is installed and the other pack houses where it is not installed.

5.5 Conclusion

The results from this study show that the implementation of the humidification system does bring about positive results in the quality of grapes distributed. However, there is a lot of room for improvement and results reveal that Company Y can begin this improvement by implementing more humidification systems into their pack houses. The results also show that more control of the temperature and RH needs to be implemented at the pack houses. Company Y can start improvements at Farm 6 where the highest number of quality concerns were identified.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

One of the main functions of a humidifier is to release moisture into the air, so that the grape in its entirety (stem and berries), may not lose moisture, post-harvest. With less moisture loss, and ambient temperatures maintained within protocol temperatures, it is less likely that the fruit will be rejected due to quality problems.

In this concluding chapter, a summary answering the research questions and final deductions from the hypothesis testing are given. The chapter is broken in sections where recommendations are given, a conclusion and possible areas for future work are also summarised.

6.2 Final synopsis

The study began with four research questions that needed to be answered. Through qualitative data that was collected through literature and an interview with the logistics manager from Company Y and quantitative data that was analysed and presented using visual aids such as graphs and tables, the research questions from this study can be answered.

1. **Does the implementation of humidifiers increase relative humidity at table grape pack houses in the Northern Cape?**
   Yes. The implementation of humidifiers in Farm 1 showed, on average the highest RH over the three seasons that were analysed. Farm 1 also identified as having the lowest percentage of QC messages across all seven farms. Farm 1 contributed 8.59% to the total number of issues compared to 20.56% of quality problems that stemmed from Farm 6. This shows that the humidification system had a positive effect on increasing the relative humidity of grapes dispatched from Farm 1. The results revealed that there were significantly higher relative humidity percentages at Farm 1 where the humidifier was installed when compared to the relative humidity of the farms where the humidifier was not installed.
2. **Does the implementation of humidifiers decrease ambient temperature at table grape pack houses in the Northern Cape?**
   Yes. The implementation of humidifiers in Farm 1 showed, on average, lower ambient temperatures over the three seasons that were analysed. The results revealed that ambient temperature was fairly stable, but generally too high across all seven farms. However, significantly lower ambient temperatures were experienced at Farm 1 where the humidifier was installed compared to the ambient temperatures of the farms where the humidifier was not installed.

3. **Does the implementation of humidifiers show a relationship between implementing the humidifier and the quality of table grapes harvested in the Northern Cape?**

   Yes, it does. The results revealed that relative humidity was fairly unstable across all seven farms and generally too low. This could be caused by the lack of control of RH, as farms showed high counts of quality issues. The quality data also revealed that 7.65% of the grapes distributed by Company Y experienced quality problems. However, the chi squared test revealed that there was a significantly lower number of quality problems where the humidifier system is installed when compared to the other pack houses where it is not installed.

4. **Can humidifiers be implemented as a standalone source of improvement for the quality of table grapes harvested in the Northern Cape?**

   Yes. The humidification system showed results of higher relative humidity percentages and lower ambient temperatures. The one farm that had the humidification system installed showed the lowest quality control messages across the seven farms that were investigated.

In addition, results calculated from the Analysis of Variance and Analysis of Covariance supplied sufficient evidence to reject the null hypothesis for hypothesis 1 and hypothesis 2. By rejecting the null hypothesis, a significantly higher relative humidity is experienced when the humidifier is installed compared to when the humidifier is not installed. Furthermore, a significantly lower ambient temperature is experienced when the humidifier is installed compared to when the humidifier is not installed. Results from hypothesis 3 showed a significantly lower number of quality problems when the humidifier is installed compared to when the humidifier is not installed. The overall data that was collected revealed that more control of both temperature and humidity needs to be investigated.

6.2 Recommendations

This study recommends that a humidification system should be installed across more farms. When installed, these humidification systems should include data loggers to constantly monitor and record data. While the pack house where the humidification system is installed did show high levels of relative humidity and lower temperature values, these levels were not maintained. This could be for various reasons. It is recommended that these units are monitored on a daily basis to ensure that they are plugged in and working properly to ensure their effectiveness. In addition, the data revealed that the various process stages encountered varied RH and ambient temperature values. This could be because of the various process stages that do not have humidifiers or could be due to the air-cooling systems installed. These temperatures are not controlled (except at the pre-cool and sluiskamer stage) and the higher temperatures could be feeding into the next process stage. It is recommended that ambient temperatures and relative humidity be monitored more closely at each process stage within the pack house.

6.3 Conclusion

In conclusion, the influence on the quality issues Company Y faced before and after the installation of the humidifier system was investigated. This investigation was done under both active and secondary data collections. Through argumentative secondary data analysis and valid results from primary data collection and statistical analysis, it was proven that humidifiers do make a positive impact having revealed a lower number of quality issues coming through the Farm 1 pack house.

From the results revealed in this study, the research questions were answered. Humidifiers do influence the quality of the various varieties of table grapes harvested in the Northern Cape. Furthermore, humidifiers can be implemented at table grape pack houses as a standalone source of improvement of the quality of table grapes harvested in the Northern Cape.

With reference to the literature review conducted in this study, there are many attributes that can affect the quality of table grapes. This study concentrated on the variables, post-harvest. As the Northern Cape went through a drought during the data collection of this study, it is not known whether this could have had any implications on the quality of grapes harvested. The installation of humidifiers has not been tried or tested by many, or many have not revealed this practice. There are high associated costs with installing a new system such as the one suggested in this study. It is, therefore, important for Company Y to weigh up the costs involved and determine whether the likely benefits to be gained are worthwhile.

The implementation of this new humidification system may not seem cost effective for a small table grape farmer, but its impact on the quality of product supplied and costs to their freight forwarders could be significant.

6.4 Possible future work

This study was conducted at table grape pack houses in the Northern Cape. Ambient temperature and relative humidity data was collected only within the pack houses. As literature revealed, temperature management throughout the cold chain of fresh produce is vital and therefore possible future work could be the investigation of relative humidity and temperature at each point in the supply chain. This could show where relative humidity may be most negatively affected and humidification systems, like the one in the study could be implemented. Data, after this implementation, could be collected and thereafter analysed and used to determine what the results reveal. The data also revealed that average ambient temperatures often reached temperatures of higher than 25°C (the recommended maximum temperature in the pack house stage). Another possible study could investigate how often/ what percentage of time the temperature is above 25°C. Furthermore, the data for this study was collected only from the Northern Cape region of South Africa. The Northern Cape is quite big and experiences different temperatures at different geographical locations. Another possible study would be to investigate the relative humidity, ambient temperatures and quality data with further investigation to see if the pack houses geographical location has any effect on the temperature of the grapes moving through and across the supply chain.

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